

METALLURGIA

The British Journal of Metals

(INCORPORATING THE METALLURGICAL ENGINEER)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

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Britain's First Post-War Year

THE year just closing is the first complete year following the collapse of Germany and Japan. It has been a year full of complexities for industry.

Many efforts to restore peace-time activities have not progressed as fast as had been hoped, and at times there has been a feeling of frustration experienced by most of us. It is probable that the fundamental changes being made in the country's economy have helped to promote this feeling, but it will be appreciated that under any political policy the main difficulties experienced during the year would have been present.

Many of us remember what happened after the 1914-1918 war and could visualise to some extent the vast changes in production and man-power involved at the conclusion of the recent war. Problems of destruction and of disorganisation have been on a much larger scale than in 1919. The occupied countries were disorganised, weakened by constant undernourishment, and in some cases depopulated by the deportation of hundreds of thousands of their nationals and the murder of thousands more. Although the relief and rehabilitation in these devastated countries have been a joint effort of the United Nations, each nation contributing to its capacity, this country, as was anticipated, has been called upon to be responsible for a large share of the relief. This responsibility was accepted with courage but it has and is gradually sapping the strength of this country, already grievously weakened by six years of war. In addition, of course, the conclusion of hostilities brought this country every possible major political, economic, and social problem, many of which remain unsolved despite the tremendous efforts made during the year to reach agreement; yet reasonably adequate solutions to these problems must be found if peace is to be made secure.

On several occasions we have stressed the fact that the change from war to peace-time activities would present greater and more diverse problems than the change from peace to war. In the latter case, almost every activity was directed to war and the nation was keyed up with the sole object of winning. To this objective the nation responded with skill, energy, and determination; even so it was several years before production could be said to supply the needs of the Forces. The change from war to peace has proved more complex, and for some reason the incentive to apply the same degree of skill, energy and determination is not so strong as under war conditions. It may be that the strenuous war years caused a reaction, when the danger of defeat was overcome, and resulted in a certain laxity

of purpose industrially. The year almost completed has not changed our view, rather has it emphasised the fact that a war of such dimensions so disturbs political and economic forces that several years must elapse before industry can become stabilised. This does not mean that no progress has been made during the year, but that allowance must be made for the disturbed political and economic background which has an important influence on industry.

Technically, considerable advancement has been made and remarkable headway has been effected in production, especially

when the unsettled conditions are taken into consideration. Exports have risen throughout the year and reached a value of £90.9 million in October. Excluding N.A.A.F.I. and U.N.R.R.A. shipments which amounted to £4.4 million, October exports totalled £86.5 million which is the highest value of commercial exports in any month since the end of the war. In volume, October exports were 117% of the 1938 monthly average; the comparable figure for the third quarter of this year was 104%. On the other hand, it should be noted that the value of imports in October was £127.4 million, the highest since the end of the war. Re-exports amounted to £4 million. Of the exports in October, metal products accounted for £41.3 million, machinery in particular showing substantial increases.

The above figures, the latest available, have been noted to show that production for export has increased, but there is still a considerable difference between the value of exports and imports which is being largely met by borrowing. It should be remembered that during the war Britain sold overseas assets to the extent of over £3,000 million to finance her war effort, indeed, she took financial knocks during that period which few countries would have survived. When it is appreciated that her public expenditure in the six years was approximately £30,000 million—about six and a half times the total net national income for 1938—the reason for the austerity of her nationals in consumer goods will be better understood.

Considering that during the war more was done with a given amount of man-power and material than in any other country, her conversion to peace-time has proceeded with remarkable speed and smoothness. Further progress in exports, however, is necessary to effect a better measure of equilibrium between exports and imports, and one of the most serious problems retarding rapid progress in the production of goods for overseas is the shortage of man-power. This is the most serious problem facing the Government and it is intensified by the fact that production per man-hour in many industries is less than during the war, while the post-war trend has

WE extend to all our readers our Sincere Greetings and Best Wishes for a Happy Christmastide; may the New Year bring all you seek.

been towards a shorter working week in all industries. Obviously the principal means of solving this problem is to make greater use of machinery which will involve much capital expenditure and considerable time. In many industries plans have already been put into operation, and in time this difficulty will be overcome, but a speedier solution would be assisted if some of the agreements between employers and employees were rescinded and new agreements entered into, more in keeping with modern industrial conditions.

But labour shortage is not industry's only problem, there is a shortage of many of the basic materials upon which industry depends. The position of the coal industry is all too familiar. At one time coal provided us with a substantial revenue, but to-day barely enough is being mined to meet home requirements. This difficulty is largely due to labour shortage. In the case of steel, however, of which there is also a shortage, production is governed by the capacity of plants manufacturing and processing it. The demands for steel exceed this capacity, and while we have been accustomed to balance the difference between our capacity and the amount required by the consuming industries, with imported steel, we are unable to import the tonnage we need. The shortage being experienced in no way reflects discredit on the iron and steel industry, which has done and is doing great work in obtaining the high tonnage from the plant capacity available. Production of pig iron during the third quarter of the year was at the rate of 7,622,000 tons a year compared to 6,893,000 tons during the same period of 1945. During the same period steel production was at the rate of 11,953,000 tons a year against 10,988,000 tons during the corresponding period of 1945. This is a substantial increase and, with the recent figures for October and November showing further increases, indicates what can be expected when the figures for the year become available.

It will be appreciated that the present demand for steel is abnormal, due in the main to the lack of peacetime steel products, at home and overseas, for the duration of the war. But, when approximate equilibrium is reached between supply and demand, it is confidently expected that a higher tonnage level of production will be needed in this country, and the plan to increase the capacity of the industry has been put into operation. It is commencing slowly, for the same reasons that are causing delays in the production of consumer goods, but it will gather momentum with time and production will gradually increase to new high levels. Meanwhile exports of iron and steel show a downward movement as a result of planned reallocation of finished steel designed to increase supplies available for the manufacturing industries.

With the exception of magnesium, which is produced in this country adequate to our needs, other base metals, either wholly or in part, are imported. Plenty of aluminium is available, supplies from Canada supplementing production in this country but, as will be noted elsewhere in this issue, insufficient plant is available to fabricate it into the forms in greatest demand. In the case of copper, as with other imported base metals, it is necessary to estimate the supply position for the near as well as the distant future. Col. Preston, Chairman of the Council of the Copper Development Association, estimates that the present difficult copper supply position is likely to last for a considerable time. Production developments are in progress in Northern Rhodesia, by the formation of the Rhodesian Copper Refiners, Ltd., but

it will be some time before production can proceed. Meanwhile, every ton of copper produced throughout the world is going straight into production, and the total is insufficient to meet present requirements. Stocks in all countries have fallen, and scrap is being absorbed without any apparent influence on the market.

From time to time it has been suggested that the lifting of controls would assist in speeding the recovery of industry, but until there is better balance between supply and demand such an action would undoubtedly hinder recovery. It is true that controls are a nuisance and tend to delay progress, either through laxity or autocratic treatment which applications for licences are sometimes given. It is certainly better, however, under present conditions, that controls should operate on a broad plan so that a reasonable balance can be maintained between the various industries with a view to establishing economic security.

On the technical side progress during the year has been steady, although there is still undue delay in applying the fruits of research. There are, of course, exceptions, and mention may be made of the materials developed for high temperature service in gas turbines. Probably the time is not far distant when research on the mechanism of creep and of age-hardening phenomena will permit the design of an alloy for a specific set of conditions rather than by trial and error. Apart from a few exceptions, British industries, in particular, are very conservative in their choice of materials and methods, and are governed, to a large extent, by established practice. However, shortages in some materials have helped to effect changes, and metallurgical developments as well as applications of many base metals and their alloys are reviewed in this issue, from which it will be noted that considerable advances have been made.

In view of the difficulties being encountered by industry, future progress is not easy to discern. There can, of course, be no doubt that the economic needs of this country can only be met by a steady and a large expansion in production. As we have mentioned, labour shortage is by far the biggest problem retarding increased production because of its cumulative effect on the erection of new plant to deal with the excess of demand over supply. Many industries are nationally minded and have planned well ahead; considerable amounts of money are being invested on new and improved plants. On the other hand, there is evidence that unscrupulous firms are cashing in on the present sellers' market and unless some action is taken to stop this short-sighted practice, the greatly increased profit it offers will cause it to grow and become a real menace to progress. On the question of labour shortage, co-operation between employers and employees, with increased production as the main objective, would enable new agreements to be entered into of benefit to the nation, and incidentally to the parties of such agreements. The same degree of skill, energy, and determination is still available and could be applied to further aid recovery, if confidence could be fully restored. Let us seek to establish confidence and many industrial problems would be simplified and Britain would again be on the high road to prosperity.

Errata

For Figs. 2 and 3, on page 4 of November issue, read Figs. 3 and 2 respectively, the block having been reversed inadvertently. For 48.1% nickel in the 6th composition of Table III, on page 6 of the same issue, read 4.81.

Plans for Increased Output of Aluminium Sheet

New Continuous-Type Rolling Mill

Although adequate virgin aluminium is available to supply the present heavy demands for reconstruction and exports, the plant capacity in this country is unequal to the task of fabricating it at the rate desired. The products of sheet and extrusions are in greatest demand and failure to meet them constitutes a bottleneck. To assist in overcoming this difficulty, a continuous-type rolling mill is being installed at Rogerstone which will be the first of its kind in the British Empire.

SO great has been the demand for aluminium and its alloys since the removal of restrictions in the use of these materials that difficulties have arisen in the supply of certain semi-finished products. Early this year we said that with the removal of restrictions it was natural that considerable attention should be given to the peace-time applications of aluminium. Keeping in mind the amount of aluminium consumed during the war, when it was applied almost wholly for war purposes, and also the fact that the number of people skilled in the working of this metal far exceeded those available in pre-war days, it will come as a surprise to many readers that there is a definite shortage.

This difficulty arises not because of any shortage of primary or secondary aluminium but of the means to convert them into the forms for which the demand is most pressing. We lack the plant to convert the quantity required and it is the production of sheet and extrusions that constitute the most serious bottleneck to speedier consumption of this material. No difficulty has been experienced in reopening the channels through which the metal contributed to industrial and household needs before the war; indeed, the peace-time uses of the metal have been greatly augmented. It should be remembered that for about six years, the people of this country and of the world generally were unable to obtain peace-time products in this metal, it is not surprising therefore, that since the war the demand has been increasing at a rapid rate and to-day the problems of supply have become almost overwhelming.

At present the unprecedented demand for aluminium sheet and extrusions cannot be met, due to insufficient rolling and extrusion capacity. While the main demands during the war were for castings, the changeover to peace-time products has caused bigger demands for sheet and extrusions. It is noteworthy that Government contracts for AIROH temporary houses are consuming 40% of the total output of these semi-finished products. A further 25% is being directed to export channels. In addition, owing to the short supply of steel and tinplate, many manufacturers of products ranging from metal boxes to ships are seeking substitute materials, of which aluminium is often the most suitable. Doubtless, many manufacturers will revert to their normal medium when it becomes available, so that part of these uses will be of a temporary character; on the other hand, in many instances the advantages of aluminium will justify the slightly increased cost, and the change will become permanent.

In view of the pressure on the aluminium industry to meet the demands for sheet and extrusions some indica-

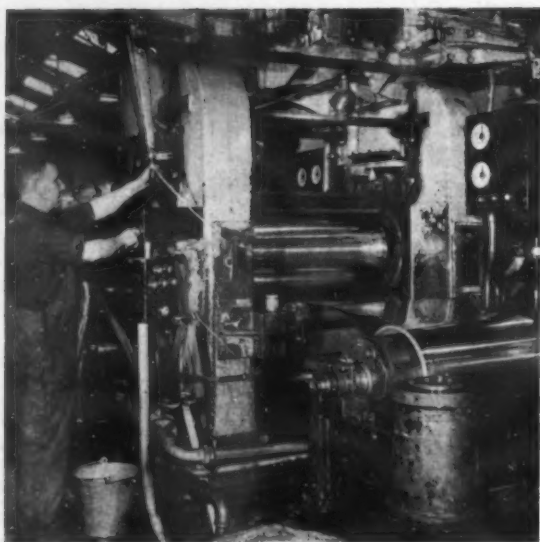
tion of the efforts made to increase production will be of interest. The Northern Aluminium Co. Ltd. advise us that their total production has been increased by six times since the beginning of the war, and that two and a half times the amount of sheet and extrusions is to-day available to industry than was the case in 1939—quite apart from the tonnage which is going into the Government housing scheme and the export market.

And the question arises, what of the future? This is not easy to answer. The future supply position depends to a considerable degree on Government housing plans. Contracts for the AIROH temporary housing scheme terminate next July, but, in view of the housing position, it is quite likely that additional contracts will be placed, either for aluminium permanent houses, or for an extension of the present scheme. Should this be so, each of the leading Companies in the aluminium industry will be called upon to contribute their quota in relation to their total output capacity. The continued shortages of steel sheet and tinplate will call for further supplies of aluminium sheet and in this field as in others, labour difficulties will continue to influence the rate of production.

In order to overcome these shortages plans are proceeding to enable the industry to produce sheet on a greatly accelerated scale. One of the most important plants producing sheet for aircraft during the war is now being expanded and modernised in an effort to cope with the increased applications of this material. The main development is a continuous-type sheet mill, the first of its kind to be installed for aluminium in this country. This mill is being erected on a 100-acre site at Rogerstone, near Newport, Monmouthshire, and its completion in 1948 will mark a milestone in the British light metal industry comparable with that reached by the steel industry in this country when continuous rolling equipment was first installed.

The only continuous rolling mills for aluminium are at present operating in the United States. British plants employ slower methods, largely because orders in the past have been relatively small and of varying sizes and not sufficient in bulk to warrant the cost of installing a continuous mill. The great development in the applications of aluminium sheet, however, have emphasised the need for increased speed in production and the expansion at Rogerstone, embracing a main series of stands and machines more than a quarter of a mile in length, will result in production methods as efficient as those in any country.

The cost of the plant and equipment involves an expenditure of more than £2,500,000 by the Northern



One of the stands of the strip mill.

Aluminium Co. Ltd., which is one of the largest associates of the Canadian corporation, Aluminium, Ltd. This investment indicates the new importance of the United Kingdom as a market and as a centre of aluminium fabrication. An output of 50,000 tons of sheet products per annum is planned from the initial installation of the new equipment, but it is announced that this can be extended to 150,000 tons if necessary. Some indication of the contribution this plant will be able to make in meeting demands is shown by comparison with existing plants operating in this country. During the war, for instance, the highest annual rate of aluminium sheet production from all plants operating in the United Kingdom was just over 100,000 tons.

The engineers of the Northern Aluminium Co. Ltd. have been working on the expansion plans since the end of the war. They have been able to draw on technical assistance in Canada where Aluminium, Ltd. owns the Empire's largest smelters for the production of primary aluminium. Even before the war, Britain obtained a large part of her primary aluminium requirements from Canada and it will be known to readers that a contract was entered into by the Ministry of Supply early this year for the purchase of 215,000 short tons from Canada over this and next year. The expansion of fabricating facilities in this country indicates a further integration of Aluminium, Ltd.'s position within the British Empire. Canada in turn depends on British Guiana for its supply of the raw material, bauxite.

The Rogerstone site was originally occupied by a steel works, but in August, 1939, it was taken over by the production department of the Air Ministry and allocated to the Northern Aluminium Co. Ltd. for the production of aluminium alloy sheet and extrusions for aircraft of all types. Key engineering staff moved into the factory a few days after the declaration of war and in record time material was being turned out. In less than four months many new buildings had been erected and new equipment was operating. By the end of 1943, the scheduled output had been increased to five times the



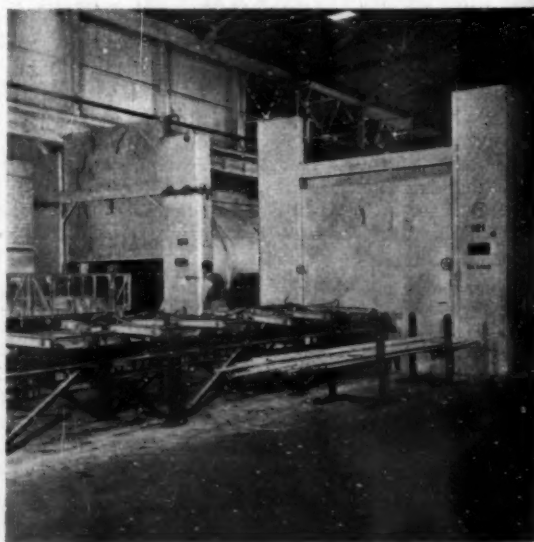
A general view of the tandem mills.

original target, thus making the plant the biggest of its kind in the country.

During the days of peak war production more than 8,000 previously inexperienced workers were employed, the majority of them drawn from the depressed areas of the Western valleys. The wartime work was the production of aluminium sheet and extruded sections for airframes, forging stock for airscrews, tubes (including the Spitfire spar boom) and wire for rivets.

In June of this year Northern Aluminium Co. Ltd. acquired the plant on a permanent basis, and the new expansion plans were put into motion. In view of the urgency every effort is being made to speed up their completion.

Heat-treatment plant.



and although the date on which the new mill will be put on production cannot yet be given, it is certain that in the first full year of its operation, the Rogerstone plant will make a very substantial contribution towards fulfilling the increasingly large demands for aluminium sheet, both in the home and in export markets.

The hot train will comprise two-high reversing mills, followed by two four-high mills in tandem, while the cold train will be all non-reversing mills, some of which will operate in tandem. The firms responsible for these mills and the auxiliary equipment include: H. H. A. Robertson & Co. Ltd., Davy & United Engineering Co. Ltd., Brightside Foundry & Engineering Co. Ltd., Head Wrightson & Co. Ltd., while British Thomson-Houston

Co. Ltd. are responsible for the electrical equipment. The strip mill is designed to roll a maximum width of 54 in.

It will be seen that little relief can be expected in the near future. The trend appears to be that current supply difficulties will continue over the next eight or nine months, and will then gradually improve until the end of 1948, when considerable improvements can be anticipated. Towards the end of 1947 it may be possible to increase the allocation to products for the home market—as distinct from the aluminium housing programme—to some extent, but for the next two years, at least, the “sellers market” in aluminium sheet and extrusions is likely to continue.

National Metallurgical Laboratory for India

Some Details of the Final Scheme

A scheme to establish a chain of research laboratories, to be sited in different parts of India, has been under consideration for some time. One of these is a National Metallurgical Laboratory to be built at Jamshedpur, the foundation stone of which was laid last month by the Hon. Mr. C. Rajagopalachari, Minister of Education and Arts, Central Government. The final scheme has been approved by the Governing Body of the Council of Scientific and Industrial Research, brief reference to which is given in these notes.

THE Council of Scientific and Industrial Research, under the auspices of the Government of India, has a programme to establish a chain of research laboratories to be sited in different parts of India. One of these is a National Metallurgical Laboratory, the foundation of which was laid last month at Jamshedpur by the Hon.

Mr. C. Rajagopalachari, Minister of Education and Arts, Central Government. The final scheme for the establishment of this Laboratory was approved by the Governing Body of the Council of Scientific and Industrial Research on September 17th, 1946, so that no time has been lost in making a start on the building of the Laboratory.

A tentative scheme for the establishment of this Laboratory was first circulated in 1945; it was estimated to cost Rs. 60,00,000 (£455,000). Modifications were made to the original scheme following suggestions and comments received from research workers of repute and on the basis of the funds available with the Council of Scientific and Industrial Research for the purpose. As soon as the final scheme was decided upon immediate steps were taken to give it effect, and those responsible for this major development are to be congratulated on the speed in making a commencement to erect the buildings.



A drawing of the National Metallurgical Laboratory at Jamshedpur on which building has commenced.

It is noteworthy that the Laboratory is to be located at Jamshedpur which is the centre of modern metallurgical industries in India. The Tata Industries, Ltd. generously placed at the disposal of the Council a very suitable site for the building, close to which are adequate services of electricity, water and gas.

When completed the Laboratory will cover all aspects of metallurgical research, both fundamental and applied, and will also carry out research on ores, minerals and refractories as applied to metallurgy. The preparation of minerals and ores and the smelting of the latter are so definitely a part of the development of the country's metallurgical industries that the facilities for mineral research have been provided, complete with pilot plant equipment for semi-commercial development.

As the metallurgical industry is one of the biggest consumers of refractories, research on this subject has also been associated with that on metallurgy, and that

the work on metallurgical furnace design might also be undertaken. Work on refractories will be greatly facilitated by the presence of the ore-dressing and minerals research section with its specialised laboratory and pilot plant assemblies.

Provision has been made in the final plans for administration, including statistics, library, museum, etc., chemical analysis, physical chemistry, physics as it affects metallurgical problems, the examination, preparation and smelting of metallic ores, the melting, heat-treatment and working of metals and alloys, research into the structure and physical properties of metals and alloys, the electro-deposition and surface treatment of metals and research on refractories. Facilities will also be provided for the application of research results to commercial operating conditions and for the study of such conditions as they affect the quality of the products and the efficiency and economy of commercial production. The Laboratory will work in close collaboration with the other laboratories of the Council particularly on long-term research of a fundamental nature.

The Laboratory will consist of a main building containing administrative offices, research laboratories, museum, lecture theatre, library, etc., and a separate technological block comprising large workshop type laboratories with associated control rooms for practical semi-commercial scale operations. The main building will face north-north-east and will have three floors. The administrative section is centrally located on the second floor. In this section facilities for statistical investigation, not only for compiling metallurgical trade figures but also for the use of statistics as a research tool in investigations on practical production and operation problems will be provided. The actual working floor area on the first floor is approximately 26,000 sq. ft., with an equivalent space on the ground floor and about 8,600 sq. ft. on the second floor. The laboratories and the administrative

section in the main building will be air-conditioned by refrigeration system.

The technological block providing a working floor area of about 28,000 sq. ft., has been situated to the south of the main building and connected to it by corridors in the form of covered ways. The block consists of four main workshops or bays, each measuring 100 x 40 ft. These bays are situated two on each side of the electrical power distribution station (100 x 40 ft.) which is located in the centre. This arrangement permits the installation of generators, controls, etc., for the furnace bay on the left, and motors, etc., for the mechanical treatment bay on the right. Furthermore, the arrangement ensures the central power distribution station against dirt, dust, fumes, etc. The north end of the technological block is occupied by a mezzanine floor forming upper and lower suites of rooms for offices of the operating staff, for inspection and control laboratories, for drawing offices and for specialised apparatus in connection with pilot plant work.

The initial basic staff of the laboratory is summarised as:-

1. Scientific Staff:	
(a) Director, Asst. Director and Research Officers ..	27
(b) Research Assistants	26
2. Technical Staff (Mechanics, etc.)	25
3. Laboratory Assistants	24
4. Administration	18
5. Laboratory Bearers	33
Total	153

The total cost of construction and equipment of the laboratory is estimated to be Rs. 42,80,000 (£325,000). Buildings, services, air-conditioning, heavy electrics, etc., are estimated to cost Rs. 25,00,000 (£190,000) and for equipment a provision of Rs. 17,80,000 (£135,000) has been made. The recurring expenses after the laboratory is in operation for five years are approximately estimated at Rs. 6,00,000 (£46,000).

Copies of the detailed scheme can be obtained from Dr. G. P. Contractor, c/o Research Laboratories, The Tata Iron & Steel Co., Ltd., Jamshedpur, India.

Manganese Wheels for Cranes

COMPELLED by the necessity for frequent renewal of crane and trolley wheels, with consequent loss of production and abnormal resulting expense, Hadfields, Ltd., of Sheffield, determined on the bold experiment of using their "Era" manganese wear-resisting steel for this duty. The initial problems once solved, the success of the experiment exceeded expectations, and where wheels shod with high-grade shrunk tyres were in some cases requiring renewal on account of wear or looseness after only three to four months, manganese wheels have endured for three years and give promise of many years life before needing replacement.

Owing to the peculiarly intractable nature of manganese steel from the point of view of machining the design of a successful crane wheel presented certain problems. The ultimate solution is a wheel in which body and tread are cast as a single piece and finished to profile by grinding, thus eliminating all question of tyres stretching and calling for renewal on account of looseness—a trouble of frequent occurrence with normal designs in which a tyre-steel rim is shrunk into position on a cast iron or steel centre. In order that drilling for the attachment of driving gears can be carried out, insets of mild steel are cast in at the appropriate points; the gear is correctly positioned by means of a ground spigot.

Manganese steel, in its toughened condition, is com-

paratively soft until it becomes work hardened in service, with the result that, in early life, the tread and flanges take an excellent surface, which, hardening itself in the process of forming, possesses outstanding qualities of endurance. This tread is kindly to the track and exhibits less tendency to seize on the rail and to cause the crane to "wind" than the normal tyre wheel.

Many patterns are in existence ranging from 36-in. dia. on tread with bronze axle bushes for 75/100 ton cranes to 18-in. dia. with roller bearings for 12-ton trolleys operating on sharp curves feeding furnace charging machines, while designs are also available with dead centres for live axles.

Satisfied by extensive experience in their own works as to the success of this innovation, Hadfields are now prepared to supply manganese steel wheels both to crane makers and to users, and point out that they can be made interchangeable with existing wheels, thus involving no alteration to standard designs or expense in adaptation.

Mr. LAWRENCE J. A. HAYWOOD has been appointed chief chemist to Messrs. Cattow & Co. Ltd., Yorkshire Steel Foundry, Hunslet. Mr. Haywood has been connected with a number of steelworks in Sheffield, more recently he was with Messrs. David Brown & Sons, Ltd., Huddersfield.

Comparison of Electroplated Finishes under Humidity (K.IIO) Test

SOME tests were discussed and results given by Mr. E. E. Halls in our October, 1946, issue on cadmium plate and passivated cadmium plate coatings in which it was indicated that chromate passivation adds serviceability to the coating out of all proportion to the small effort and cost in its application. Some comments on this article by Mr. Frank Taylor, together with a reply by Mr. Hall, were published in our last issue and were concerned with other plating finishes. In his comments Mr. Taylor referred to some comprehensive tests which had been

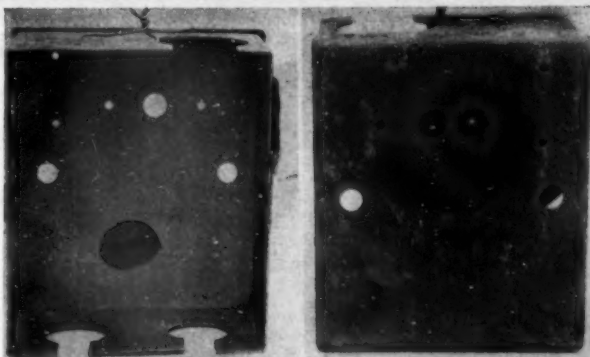


Fig. 4.—Zinc, chromate passivated. Average thickness = 0.0008 in., min. thickness = 0.0005 in.



Fig. 1.—Cadmium, chromate passivated. Average thickness = 0.0005 in., min. thickness = 0.0003 in.

Fig. 5.—Zinc, phosphate passivated. Same thickness as sample 4.

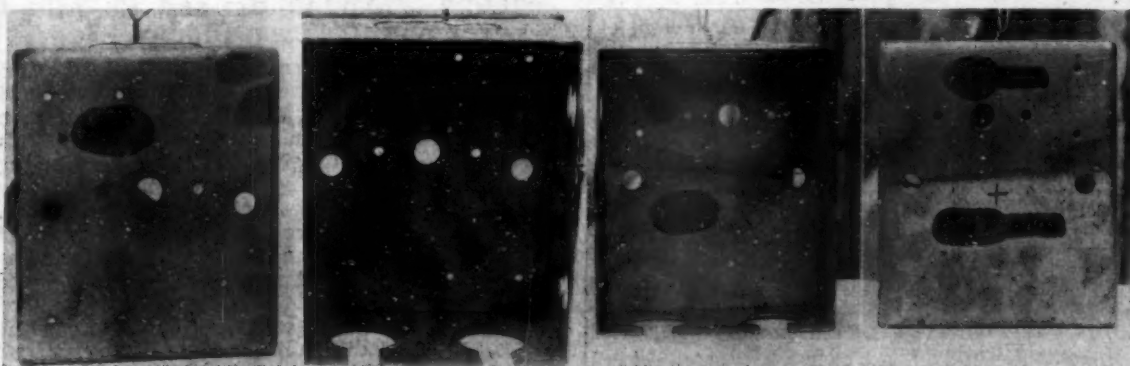


Fig. 2.

Fig. 6 & 7.

Fig. 2.—Cadmium, plain. Average thickness = 0.0008 in., min. thickness = 0.0005 in. Fig. 6.—Nickel plated + tin plating. Average nickel thickness = 0.0015 in., min. = 0.001 in. Average tin thickness = 0.0002 in.

Fig. 7.—Nickel plated. Average thickness = 0.0015 in., min. = 0.001 in.

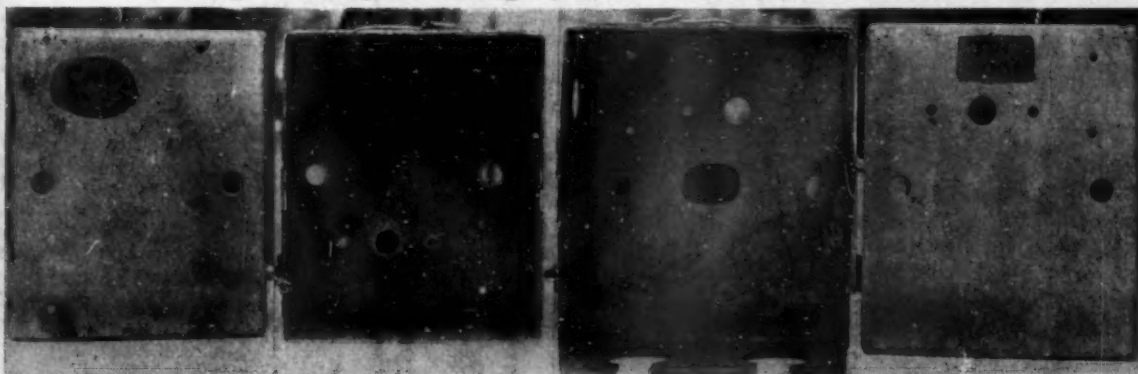


Fig. 3.—Cadmium, plain. Average thickness = 0.0005 in., min. thickness = 0.0003 in.

Fig. 8.—Tin (acid) plated. Average thickness = 0.0014 in., min. = 0.0009 in.

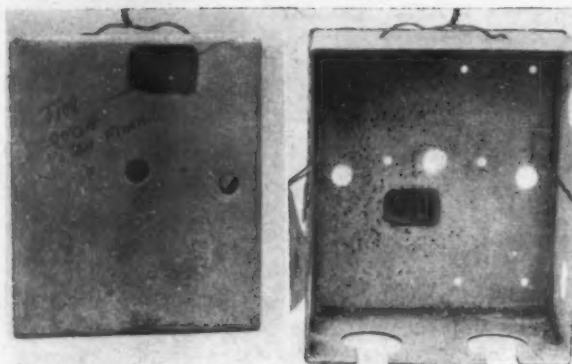


Fig. 9.—Tin (alkaline) plated + zinc flash. Average tin thickness = 0.00036 in., min. thickness = 0.00012 in. Average zinc thickness = 0.0001 in.

carried out on behalf of Government departments to compare plain cadmium and passivated cadmium plated surfaces with plain zinc, passivated zinc, plain tin, passivated tin, and composite deposits under humid conditions (K. 110 test). It was felt that the results of these tests would do much to clarify the position, and we are indebted to Mr. Taylor who has obtained permission for the publication of the results in these notes.

The accompanying illustrations show the results of the effect of 21 cycles in the humidity chamber, operating at 60° C. and at 100% relative humidity. This is the standardised K. 110 test and the results give a good idea of the relative merits of the respective deposits—viz., cadmium, cadmium chromate passivated, zinc chromate passivated, zinc phosphate passivated, nickel, nickel and tin, tin and zinc when subjected to tropical conditions.

All the boxes illustrated were processed in production vats in order to ensure that a normal production type of finish was obtained. The results of the tests are indicated under their corresponding illustrations and are given in what is regarded as their order of merit; number one yielding the best result and number ten the worst under the conditions of the test.

Very slight darkening when finger marked, otherwise no corrosion product. (Fig. 1.)

Several dark patches due to handling, generally dull in appearance, inner corners show slight seepage. General condition and appearance remains good. (Fig. 2.)

Discoloration and dullness as noted for second sample above. Slight rusting in corners and seams of inside surfaces. (Fig. 3.)

A slight corrosive growth developed during the first cycle and remained, without appreciable increase, throughout the test. No rust. General condition good. (Fig. 4.)

Corrosion began early in the test, gradually increased and finally spread over almost the entire surface. (Fig. 5.)

Finish now dull, slight rusting on the inside corners, angles and seams. A few rust spots on the inside walls. (Fig. 6.)

Dull and tarnished. Rust on inside walls, corners, angles and seams. Outer surface also shows rust along joints. (Fig. 7.)

Dull, tarnished and discoloured, rust along the edges and seams. Fine rust showing at many points on the inside surfaces. (Fig. 8.)

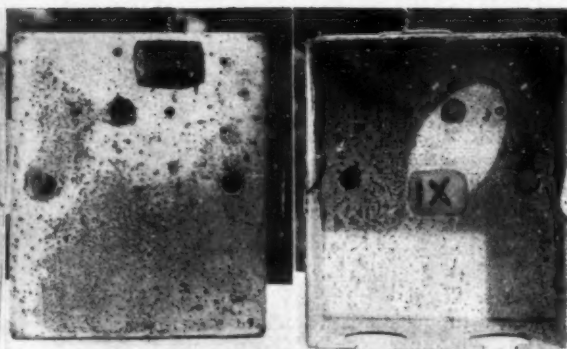


Fig. 10.—Tin (acid) plated. Average thickness = 0.0007 in., min. = 0.00045 in.

Corrosive growth developed rapidly during cycles becoming heavy before reaching the fifth. Slight general rusting appeared after the sixteenth cycle and spread slightly until the end of the test. (Fig. 9.)

White corrosive film appeared during the first cycle increasing very slowly. Faint rust showed after the fourth cycle, spreading gradually over the whole surface, finally showing extensive rusting. (Fig. 10.)

From a comparison of the above results it will be readily appreciated that, under the conditions of the standard (K. 110) test, chromate passivation in the case of cadmium and zinc is definitely advantageous and beneficial.

Forming of Aluminium and its Alloys by the Drop Stamp

THIS 24-page bulletin describes and illustrates the rope and air operated drop stamps and continues to give much information on the design of tools for the drop stamp and the materials suitable for such tools. Details with section drawings are given for the process of making drop stamp dies beginning with construction of the drawings from which sheet metal templates are made. This section also describes and illustrates processes of casting the die and the punch and methods of mounting punch and die. Drop stamp technique is illustrated by working diagrams showing tool dimensions, and different stages in the process. The use of pressure plates, progressive dies and rubber pads is also described. After dealing with the control of wrinkles, final straightening and stamping and shearing, the bulletin concludes with a note on the use of the drop stamp in conjunction with the power press. This is one of The Aluminium Development Association's Bulletins (No. 12) and it is in conformity with the high standard set in earlier Bulletins. Copies are available from the Association, 67, Brook Street, London, W. 1.

COMMANDER E. H. M. NICHOLSON, who recently retired from the Board of Hadfields, Ltd., Sheffield, was entertained to dinner by his fellow directors, recently, at which Lord Dudley Gordon (Chairman of Hadfields, Ltd.) presented him with a silver salver bearing the embossed signatures of his colleagues as a memento of his long service with the company, and to mark the respect and esteem in which he is held throughout the works. Mrs. Nicholson was given a dressing-table set.

GOLD IN BRITAIN

By J. E. Metcalfe, Assoc.Inst.M.M., Assoc.M.I.M.E.

Although the immediate need in Britain is for domestic base metals, gold is economically important as a currency stabiliser, and its potentialities in this direction should not be overlooked. It is probable that the recently formed Mineral Development Committee will consider prospecting and exploration in the few gold-bearing areas of this country. The results from these areas are briefly reviewed, and the suggestion is made that any action taken would be Government-sponsored.

THE terms of reference of the Mineral Development Committee, the formation of which was recently announced by the Minister of Fuel and Power, are: "To inquire into the resources of minerals in the United Kingdom, excepting coal, oil, bedded ironstone, and substances of widespread occurrence; to consider possibilities and means of their co-ordinated, orderly and economic development in the national interest, and to make recommendations in regard thereto."

It will be interesting to see if the activities of the Committee are to include the direction of prospecting and exploration in the few gold-bearing areas of the kingdom. It cannot be said that the three most promising areas—South Wales, North Wales and Southern Scotland—have been prospected nearly as widely as the great goldfields overseas; mining has been shallow in depth, and, as for lateral exploration, there is nothing beyond ancient surface and sub-surface workings and such restricted crosscutting and diamond drilling as has been allowed by the finances of modern operators.

Any future consideration of Government-sponsored prospecting, then, can be based on three premises: (1) Gold does exist in Britain, but in unknown quantity; (2) prospecting and mining in the past have been on a small scale due to lack of one or more of the following—technical knowledge, capital, suitable equipment, inducement and public interest; and (3) no fortunes have yet been made out of British gold-mining. In each of the three main areas now to be reviewed—no attention will be paid to minor gold occurrences—there is quite conceivably a mother lode still to be discovered.

South Wales

In Carmarthenshire the area between Llanwrda and Lampeter, west of Llandovery, was worked by the Romans, who left a long adit, a number of stopes and open-cast excavations and various relics. The lodes, which conform to the folds of the Silurian shales, are of two types: (1) Quartz with free gold and sulphides in partings in the shale, and of which the hanging-wall is remarkable for a rippled effect; and (2) well-defined auriferous pyrite impregnating, and sometimes completely replacing, the shale.

After the departure of the Romans the deposits were apparently untouched until the 19th century, when small-scale attempts, many of them successful, were made to extract the ore. About 1910 a Cornishman called Mitchell sank a shaft to 100 ft. and did some mining and crushing, but there are neither plans nor records of his work, and it is feared that he, in common with his predecessors, gave up for want of capital.

Then on December 27th, 1934, was formed Roman

Deep Holdings, Ltd., who acquired mining rights over 3,500 acres at Pumpsaint. This parent company gave birth to an operating company, British Goldfields (No. 1), Ltd., on April 6th, 1937, who acquired 230 acres for the working of Ogofau Mine. (The old name was Gogofau). Mitchell's shaft was deepened to 480 ft. and stations were cut at 160, 260, 360 and 460 ft. Milling started in January, 1938, but stopped in October of the same year; diamond drilling and crosscutting were continued for a while, but all operations, including pumping, had ceased by the end of 1939. On the whole, it is said, results were disappointing, due chiefly to the dilution of ore by country-rock; but it cannot be denied that the enterprise was unfortunate in being started at such a time, and no domestic gold-mining company could hope to keep going when many profitable mines overseas were compulsorily closed down.

North Wales

Gold-mining in Merionethshire, north of the River Mawddach, has had a relatively distinguished history—from 1862–80, the recorded output was over 15,000 oz.—but here again there was a long lull between the Roman period and the 19th century. The auriferous veins, trending E.-W., are at the junction of the Lower and Upper Cambrian where the Lingula Flags of the latter rest upon the grits and quartzites of the former, and are supposed to be richest at points of intersection with base-metal and non-metallic veins trending N.W.-S.E. and N.E.-S.W.

In 1843 Arthur Dean found that many of the lead and copper lodes were impregnated with gold, and after Parry and Williams in 1854 discovered gold in the Vigra and Clogau copper mine they succeeded in extracting £36,000 worth. A boom in Welsh gold-mining followed and many companies were floated, some of the mines started being Berthllwyd, Cwmeisen, Dolfrwynog and Gwynfynydd. Much disappointment resulted and only a few mines kept going, notably Vigra and Clogau, where the output in 1875 was 548 oz. and in 1879 447½ oz. (Gold was then 78s. per oz.) In a report on this mine, issued in 1875, it was stated that the average value of the rough ore was 7–8 dwt., but from one of the rich stockworks 9,310 tons yielded 12,416 oz. of 22-ct. gold—nearly 1½ oz. per ton. The Gwynfynydd Mine closed down in 1916, but was given a flicker of life in 1922 when enough gold was extracted for Princess Mary's wedding-ring. The Prince Edward Mine was worked for some years after 1924.

Local affection for gold-mining did not flag, however, and in 1930 the Merionethshire Development Committee requested the Secretary for Mines, then Mr. Shinwell, to

authorise an inquiry into the possibility of developing the production of gold in the county. Accordingly in October Professor Henry Louis, as the appointed Commissioner, held court at Dolgelley and listened to the evidence of mining engineers and miners, nearly all of whom were enthusiastically in favour of revival. It was something of a historic occasion, and some interesting facts and opinions emerged. Allegations were made of past incompetent and slack management, inefficient milling, and, perhaps most serious of all, wholesale pilfering of gold. Two other factors blamed for the decline of the industry were lack of cheap power and inordinate taxation, both of which had crippled the owners, most of them proverbial "small men." Contrary to expectations the inquiry did not result in a local industrial revolution, but those who ought to know say there is still plenty of payable ore to be mined if only there were capital for prospecting.

Southern Scotland

The geology of that area of Scotland south of the great Southern Upland Fault is similar to that of Carmarthenshire, and metalliferous veins traversing the Ordovician and Silurian strata have been worked in the Leadhills (Lanarkshire) and around Wanlockhead (Dumfriesshire) and Newton Stewart (Wigtownshire). Although there has been no underground mining for gold, alluvial deposits have been worked in streams in the Leadhills and near St. Mary's Loch in Selkirkshire. Gold-mining here (if such it can be called), unlike that in Wales, flourished to some extent in the Middle Ages, and in 1424 the Scottish Parliament granted its country's gold mines to the Crown. In recent times there have been no attempts to revive the old industry or indulge in serious prospecting.

The deposits which, historically at least, are of most interest are those of Crawford Moor (or Muir) in the Leadhills, which from 1511-13 were worked by Sir James Pettigrew on behalf of James IV. A company of Germans and Dutchmen laboured for some months in 1526, but do not seem to have made much profit. In 1568 a 19-year lease was granted to Cornelius de Vois, a Dutchman, who raised £5,000 from Scots subscribers, gave employment to 120 men, washed appreciable quantities of gold from the streams, and in one period of thirty days, it is told, sent 8 lb. of pure gold to Edinburgh. Leases were granted to several other foreigners, but, possibly for reasons best known to themselves, there are no records of the extent of their successes or failures.

Perhaps the most romantic of the adventurers, however, was an Englishman, Stephen Atkinson. At first a "finer" (assayer or refiner) in the Tower of London, he was later engaged by Sir Bevis Bulmer—one of the earliest real mining engineers—to assist him in the exploration of mines in Scotland and Ireland. Then in 1616 James I gave Atkinson leave to search for gold and silver on Crawford Moor on condition that the King received 10% of the profits. In five years Atkinson spent £3,000 of the king's money to negligible effect, and in self-vindication wrote a book "in respect of the wonderful resemblances which many of his Majesty's gracious deeds have with the doings of the prophet David and Solomon the wisest." James was unmoved by this eulogy, however, and stating that the mines had "bene thir divers zeiris bygane neglectit," transferred the lease to a John Hendlie, physician, of whose activities we have no record.

Conclusion

It is true that the more immediate need is for domestic base metals—tin, lead and zinc—but in a long-term policy gold is economically important as a currency-stabiliser and British potentialities in this direction should not be forgotten. Prospecting is the prime consideration, for no easy strikes or Klondykes can be expected, and although there may be workable deposits yet unproved it will probably take a great deal of expensive drilling, crosscutting and perhaps geophysical work, to locate them. In this age of successful overseas mining organisations it is extremely doubtful if either the share-buying public or the mining groups themselves could be induced to provide the necessary capital for gold-prospecting at home, and hence if any action at all is to be taken it must be by the Government—which only means, of course, that instead of the expense being borne by a comparative few it will be spread over all taxpayers. Mining engineers employed by the Government have already shown what can be done for the prospecting of coal in a time of national need, and it is hoped that as a result of the formation of the Mineral Development Committee the prospecting of metals will be placed on a similar footing. Even if gold is not considered worthy of individual urgent attention it may be that, occurring as it does in known mineralised zones, extensive prospecting for other metals will disclose it incidentally.

The writer feels bound to remark that in this article he is neither advocating wholeheartedly the spending of national money on gold-prospecting nor repudiating the future gold-mining possibilities of the country, but has simply attempted a brief review of past endeavour to show that there definitely is gold in the United Kingdom and, perhaps, to stimulate in others an interest in its occurrence.

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REVISED technical data sheets have been received on standard aluminium casting alloys. In addition to a summary sheet tabulating ten alloys with brief reference to their mechanical and physical properties, casting characteristics and general uses, fuller information is given which provides a useful guide to the selection of these alloys, their general properties, and mechanical properties. One table indicates the relative casting characteristics and mechanical properties of the alloys, and also their approximate relative value expressed in units. Individual data sheets received give very full information on the aluminium-silicon casting alloy L. 33, Alar 00-12, Alar 00-5, L.A.C. 112A; the aluminium casting alloys D.T.D. 424 and D.T.D. 428; and the aluminium-copper casting alloy L.A.C. 10. These sheets will be invaluable to makers and users of aluminium castings; they are published by Alar, Ltd., 35, New Broad Street, London, E.C. 2, and are available to readers on request to that address.

Iron and Steel Industry Progress in the Urals

By A. N. Speransky

Head of the Urals Sector Planning Commission

Largely because of the production of the Urals, Russia was at one time one of the principal producers of iron and steel. With the introduction of coal the use of charcoal gradually diminished and the Urals ceased to have importance in Russia's iron and steel industry. Since the revolution, however, great progress has been made in developing the iron ore resources of this area, and the author outlines briefly some of these developments.

THE exploitation of the iron ore deposits in the Urals began in the 16th century by the brothers Stroganov, to whom land was given by the Moscow Government in 1558. Later, Peter the Great founded several ironworks and after the discovery of gold in the area in 1745, colonisation proceeded rapidly. Thus, early in the 18th century a large industrial district began to develop, and, since numerous iron ore deposits in the area were associated with abundant timber and water power resources, the iron industry developed. Indeed, largely as a result of developments in the Urals, about the year 1769 Russia attained the unusual output of 80,000 tons of iron and exceeded the production of any other country. Russia and Sweden were then the chief iron producers. The comparative production of Sweden at that time being 50,000-55,000 tons per annum and England about 32,000 tons.

In the seventies of the 18th century more than 120 iron works were in operation in the Urals, producing about 65,000 tons of iron per annum and the area was regarded as the world's most important centre. This position was retained until towards the end of the century, when the use of coal in England made great headway and gradually replaced charcoal as a means of reducing the ore. Further developments, including the open-hearth and Bessemer methods of steel production, which took place in England and spread rapidly to many other countries, seriously handicapped Russia and the Urals area in particular where the old puddling and charcoal processes continued to be used, and the market passed from both Russia and Sweden. Thus, the Urals iron and steel industry lost its dominating position, and the area ceased to be the chief mining district in Russia, and the Donetz basin in the south took its place. Even after the revival of the Ural iron industry in 1898, when, largely with British capital, it was developed and improved, the ratio of iron production between southern Russia and the Urals was about 70-20.

It was not until after the revolution that the potentialities and possibilities of the Urals began to be more fully understood and appreciated and its industry began to develop on a scale and in a direction corresponding with its natural riches. Gradually, development was effected gathering impetus as it proceeded as a result of measures adopted under the first and second five-year plans. By 1937-38 the industrial capacity of the Urals had increased considerably and production of iron exceeded more than ten times that of 1913. At that time the output of steel in the Urals attained 90% and semi-finished steel products 80% of the total output of Russia in 1913. The policy of concentration

undoubtedly helped the industry and, with the opening of a new base in the eastern part of the country, the reconstruction of the iron and steel works in the Urals was undertaken and a number of new ones were built. It was as a result of these plans that the first section of the large Magnitogorsk iron and steel works was built and put into operation.

Further developments were effected in the third five-year plan—1938-42—when production in the Urals was augmented by a new blast-furnace plant in the Nizhni-Tagil Works, and a large number of open-hearth furnaces and rolling mills in other works. The great increase in capacity of the Urals at this time far exceeded that of the entire iron and steel industry of Russia in 1913.

When war broke out the Urals were fully prepared to increase enormously the production of metal and machinery. During that period, factories under construction were rapidly completed and new works and plants built. Thus, for instance, 13 coke-oven batteries, 10 blast- and 32 open-hearth furnaces, 2 large Bessemer converters and 21 rolling mills (including a tube mill) were built and put into operation in the Urals during the war, also a large plant for the production of high-grade alloy steels. A large number of works in regions which were subsequently occupied by the Germans were also evacuated to the Urals.

This area became the main centre for the production of iron and steel. Indeed, during the war, output of pig iron in the Urals almost doubled, steel production increased by 1.7 times and output of coke more than trebled. The growth of production was accompanied by important reconstructions necessary to meet the demands of war industry for new types of high-grade steel and products manufactured from them. At this time the Urals supplied metal to all parts of the country.

The Future of the Urals

The potentialities of the iron ore deposits in the Urals are not yet fully appreciated. Two hundred surveyed deposits of the 1,200 known have been estimated at 2,500 million tons, and much of it is of high quality. Such rich deposits make it possible to raise the output of iron and steel in the area to 25-30 million tons per annum. So far, local coal is only used to a limited extent, most of the large plants depend mainly on coal brought from Kuzbas in Siberia and from Karaganda in Kazakhstan. Both these coals are distinguished for their high quality and low cost which largely compensates for the long haulage.

In future, with the building of the trunk railway to the north, Urals iron and steel works will receive the still better Pechora coke. Despite the long transportations

of fuel, conditions are most favourable for the development of the iron and steel industry and for reducing production cost. In the southern parts of the U.S.S.R. iron and steel works have the advantage of possessing both iron ore and coal measures on the same territory, but Donbas coal is inferior to that of Kuznetsk and Pechora and mining is more expensive in Donbas than in the other two basins. Despite the additional transport costs the iron and steel works in the Urals have begun to produce the cheapest steel in the U.S.S.R.

These features of the Urals have been taken into account in the extensive building programme under the new five-year plan for the restoration and development of the national economy of the U.S.S.R. in the 1946-

50 period. The programme provides for the completion of the Magnitogorsk iron and steel works construction which are expected to become the largest in the world.

Building of the Nizhni-Tagil and Chelyabinsk works will, in the main, be completed, and a new iron and steel works will be put into operation in the Orsk District. The latter enterprise will work on the chrome-nickel ores of the Orsk-Khalilovo deposits and will produce, on a large scale, low-alloy steels with highly valuable properties. A new ferro-alloy works is to be put into operation and the raw material base greatly extended.

As a result of the realisation of the new plan the output of iron and steel in the Urals will increase 2-5 times as compared with the pre-war 1940 year.

Tungsten Carbide Draw Dies

By Richard Saxton

Brief particulars are given of the production of tungsten carbide dies and of their design and application in the drawing of metals.

TUNGSTEN carbide dies, as employed for cold deformation in the fabrication of drawn steel bars, wire and tubes, are a product of powder metallurgy, a method of metal production for which is claimed a growing future. The method is an improvement on fusion methods of metal production, because it is possible by this process to amalgamate metals of high and low melting point without loss of metal or detriment to unit quality. The combination of tungsten and copper may be quoted as an example; any attempt to amalgamate by ordinary melting methods, results in much of the copper being driven off in the form of vapour, before 60% of the melting temperature of tungsten has been attained.

Tungsten carbide is one of the hardest metal alloys known. In addition to its efficiency as a reduction unit in the cold working of various metals, it has a high reputation as a tip for various metal cutting tools, particularly under conditions generating fairly high temperatures. As employed in fabrication of draw dies, materials are first thoroughly mixed in powder form. The constituents, in general, are mono-carbides of tungsten with cobalt or nickel as the predominating cementing agents.

Tungsten carbide is formed by adding carbon to tungsten in powder form and subjecting the mixture to a temperature of 1,500° C. in an hydrogen atmosphere. Cobalt powder is then added, and the whole mixed in a ball mill. The mixture is subsequently submitted to a pressing operation, in which the powdered metals are subjected to pressure in special moulds. These are constructed to form the rough shape of the finished die. Due to the hard nature of the finished metal, current practice is to prepare the mould so that further fabrication is reduced to a minimum. Following the pressing operation, the die units, known as "rough cored nibs," may be completed by the single or double process. In the latter process they are pre-sintered at a temperature of 850° C. in an electric furnace with controlled atmosphere. The resultant product is a chalk-like compound, extremely friable under slight pressure. In this condition further shaping can be done

to limit the amount of finishing to the final product. The final operation, that of sintering, is accomplished by subjecting the compound to a controlled time, temperature and atmospheric, heat-treatment, in which hardness quality is imparted.

Quality or character of grain formation is important, as this is a factor controlling the working life of the die, and to provide the high efficiency so essential; cooling off is regulated to impart suitable grain structure combined with physical properties necessary. The finished nib is cased to prevent its fracture under forces generated during cold working, drilled to the requisite size and section and the drawing angle or reduction zone polished.

The reduction zone consists of three parts; the entrance angle, the bearing and the back relief. Entrance angle is actually the reduction part, the bearing is a cylindrical formation at the exit of the entrance angle, and the back relief is a continuance of the bearing with expanding taper. The purpose of the cylindrical section is to obviate wear at the exit end of the reduction angle, and the back relief is to ease the tension as the fabricated material issues from the die. Various designs of dies are employed, each for a specific purpose—i.e., for the cold working of a particular quality of steel or other metal. Mild steel is reduced with a fairly open approach angle, as malleability of this quality permits heavy drafting or reduction. High-carbon steel, on the other hand, which offers greater resistance to plastic deformation, is drawn through a smaller angle, with less reduction per draft. Copper, a milder metal than steel in the annealed stage, can be reduced 40-60% smaller per draft than mild steel, without detriment to quality.

In all methods of steel reduction by cold drawing, the forces generated are compression and tension. Compression is essential to perform reduction and tension to enable compression to function. During the travel through the reduction zone the grain formation of the material being processed is elongated, with consequent reduction of cross-sectional area, and impartation of a fine, fibrous structure. The elastic limit or fracture point, under the tension imposed, varies with different

qualities, and is dependent chiefly on the degree of approach angle and resistance of material to deformation.

Surface preparation and lubrication are important factors in relation to working life of the die. Surface preparation consists of removal of surface matter and scale by immersion in sulphuric or hydrochloric acid solutions, followed by washing. The material is then allowed to stand, slightly damped, until an iron hydroxide coat is formed. The degree of coat imparted is graded to combine with number of draftings it is intended to perform, a heavy coat being imparted to material subjected to three or four draftings, and a light coating for one or two passes.

Following the formation of the iron-hydroxide coat, the material is immersed in lime liquor, placed in an oven, and dried at a temperature of 250° C. The application of heat at this stage also serves the purpose of driving off the remaining acid contained in surface indentations of the metal, which, unless eliminated, will have a detrimental affect on surface structure, generating a thick coat of dry rust after a few days exposure to atmospheric temperatures, even on completion of drawing operation.

After the dried material has been cooled it is ready for the reduction operation, and to facilitate slip during the travel through the reduction zone, it is passed through a

lubricant-soap, contained in a suitable receptacle attached to the die holder. The lime picks up the lubricant-soap as the material passes through the container, and carries it into the reduction zone. Due to compressive stress engendered, a tube composed of soap lubricant, lime and iron hydroxide, is formed, and within the tube the material forms a solid core of steel, keyed so tightly to the encircling tube, as to be carried along with the resultant reduction. It will be noted that though the material is reduced by the compressive forces induced by travel through the reduction zone, the metal surface does not contact the die face. Any occurrence of this nature is usually due to inefficient surface preparation, and the resultant friction quickly leads to spoilation of the die as an efficient unit for the particular diameter desired.

In plastic deformation as in the cold drawing of steel bars and wire, uniform slip of grain formation is essential. Two kinds of slip take place during reduction: the slip of crystal cleavage planes and slip between between crystals, known as internal and external slip. It is claimed by many authorities that when initial yield has taken place and the material hardened against slip on the same planes, there is a proportional decrease in internal, and increase in external slip, leading, if carried to excess, to fracture of material.

The Phosphatising of Zinc Surfaces

Communication from Mr. E. E. Halls

THE note in METALLURGIA, October, 1946, p. 320, on the protection of zinc surfaces by phosphating is in itself very interesting, and it raises a number of important points. Mr. Frank Taylor's comments in the November issue, p. 36, cover some controversial features.

Although phosphatising has been mainly used on iron and steel as the most effective preparation for subsequent painting or varnishing, the impression must not be gained that the main virtue of this treatment is an adhesion promoting function. It is true that the properly executed phosphate coatings probably confer upon the ferrous metals the best known "Key" for applied organic finishes, but in conjunction with the latter truly rust-proof finishes are obtained in the sense that the preparatory treatment inhibits the natural ageing of the organic coating, preventing premature embrittlement and loss of adhesion tends to prevent rusting through a properly applied coating, or beneath it, and, where the coating becomes fractured, it localises the rusting to the bared area and retards spread of rust from the affected spot to surfaces beneath the organic coating. It is evident that exposure conditions can always be produced, and in fact, are often encountered in practice, in which steel work will rust whatever the applied finish. Ferrous components phosphatised and "painted" will ultimately fail, dependent upon the composition of the applied finish, and upon the nature of the exposure conditions. Nevertheless, compared with the same work, with the same finish except no phosphatising, under the same conditions, the life of the phosphatised components is so extended as to be quite disproportionate to the cost of this item of processing.

Phosphate processes have been in operation for over forty years. Coslett's name is recorded as one of the earliest of the pioneers of industrial applications, ref. B.P. 8667, 1906. In a relative sense, the process has always been a success, but it is during the last twenty years that the engineering industry in general has shown real appreciation of the advantages of phosphate treatments, and that they have been intelligently used properly controlled and exploited to marked economic advantage.

The early processes gave variable results, were difficult or impossible to control, and in consequence very costly to operate. In answer to any comments upon monopoly, it is considered that credit must unreservedly be given to the Parker Rustproofing Corporation of America, ably assisted by the Pyrene Co. Ltd. in this country for the present position attained by the phosphate processes. The research work underlying the mechanism of the reaction, the balance of the chemical solution employed, its simple control under production conditions, and the formulation of modern rapid processes, is immense. The method of treatment of different metals, of the same metal in different physical conditions or in the form of a miscellany of components, has required a sound technical background, and a wealth of experience. The cost of chemicals supplied as proprietary mixtures by these concerns, regarded in the bare manner of price per pound, is high, but it is obvious that among other things, this price must cover the research work involved in the development, maintenance, and improvement of the existing standards. It is likewise evident that finality can never be reached, and the work behind the scenes must continue. The real measure

of cost is the quality of the article produced in relation to a predetermined standard, the obtaining of this standard with the minimum of effort and wastage, and the service performance without premature failure and thus without further wastage. This question of wastage is one of national and international importance. For the provision of a specified standard of performance, phosphatising enables fewer coats of paint or enamel to be employed, and thus saves paint, power and labour. It also yields a more durable job, and again represents a saving in these directions.

Any new processes introduced in the future have a very high standard already established that must be equalled or surpassed. It is naturally helpful to have the stage attained by the Parker and Pyrene processes, or the American Chemical Paint Co. and I.C.I. granodising processes, or the much newer Rovaline and Walterisation treatment, from which to start, but the knowledge acquired from many years of development and application is not easy to attain in a short time. The user must definitely require his chemicals at the lowest possible price level, but he will require intensive pressing before agreeing to carry out large scale trials on completely new processes until it can be demonstrated that they possess the right standard of efficiency, and above all are easily controllable. Somewhat similar remarks apply to the user preparing his own chemical mixtures. As far as the writer is aware, the patent situation has not prevented

this from being done within the last few years, but it does not appear to have been the practice. The fundamental fact restricting this activity is that most large users are engineering concerns, and their chemical activities are largely if not fully occupied in controlling materials and processes, or in developing components used in the product. Rarely have they the research effort to spare in fundamental chemical development work of this nature.

Regarding the application of phosphate processes to zinc, this has been generally established in this country for about ten years, but not to all forms of zinc. Diecast zinc components represent the most general zinc base material successfully dealt with in this manner. Electro-zinc coatings have given variable results and require rather special consideration. Hot-dipped zinc coatings likewise do not appear to have given uniformly excellent results from all types of solution available, although they respond very well indeed to specific phosphate treatments. There are thus a number of individual factors to be taken into consideration before thinking in terms of a universal treatment for zinc. It may be that the features patented by the Westinghouse Electric Corporation will contribute to this end.

Some account of phosphate treatments for zinc, and for plain iron and steel, will be presented shortly with special reference to the results obtained from the user's viewpoint.

High-Silicon Iron Castings

A SERVICES Specification, B.S./S.T.A. 25, issued by the British Standards Institution for the Ministry of Supply, deals with high-silicon iron castings. The material is specified to contain 0.35-1.0% carbon, 14.25-15.0% silicon, not more than 1.0% manganese, not more than 1.0% phosphorus, and not more than 0.1% sulphur. Castings for certain duties may have a silicon content less than 14.25%.

All castings should be heat-treated. They should be stripped from the mould whilst hot, and as soon as possible after solidification, and charged direct to a furnace previously heated and maintained during the period of charging the castings at a temperature in the region of 600°C. When the furnace is finally charged, the castings should be uniformly heated to a temperature of not less than 750°C., and not more than 850°C., and soaked at this temperature for a period varying from two hours for small simple sectioned castings (i.e., castings of simple form and maximum section of $\frac{3}{4}$ in.) to four to eight hours according to section and design for heavy castings of intricate design and varying section (i.e., castings with minimum section greater than $\frac{3}{4}$ in.). After soaking, the castings should be slowly cooled in the furnace, and not removed until the temperature has fallen below 300°C. After cooling and fettling, castings should be examined to ensure that they are free from abnormal surface imperfections or cracks.

When high-silicon iron castings have to be welded either for repair or for the fabrication of composite fittings, the components to be welded should in all cases be carefully preheated and maintained at a temperature not less than 650°C. throughout the whole of the welding operating. The welded component should be slowly cooled after welding, using the preheating equipment

to control the rate of cooling or alternatively placing the welded component, immediately welding is completed, into a furnace previously heated to a temperature not less than 400°C., and slowly cooled in this furnace. The weld metal deposited should have the same general composition as that of the parent metal, and should not be lower in silicon content than the parent metal.

Two booklets have been received which describe new products of the Metals Division of I.C.I., Ltd. One concerns "Kutern," a material possessing the properties of copper but capable of much quicker and easier machining to a fine surface finish. The other gives information about "Kumium," a copper-chromium alloy which retains its tensile strength, hardness and conductivity at very high temperatures. The properties of these materials are given, together with some applications. Copies of these booklets may be obtained from Imperial Chemical Industries, Ltd., 42, Hertford Street, London, W. 1.

A BOOKLET of 48 pages has been issued on precision heating for light alloys by Templewood Engineering Co. Ltd. Heat plays a very important part in the successful production of light metal components, as with components in other metals, but probably the need for accurate control of the heat is greater. This booklet illustrates and describes melting and heat-treatment furnaces which have been installed specially for the light metals. It is emphasised that each new installation must be designed and constructed to meet the variable duty demands, space and fuel, etc. This booklet is available on application to Templewood Engineering Co. Ltd., Eastbourne Road, Trading Estate, Slough, Bucks.

The British Cast Iron Research Association

Silver Jubilee Celebration

From a relatively small beginning in 1921 the above Association has grown in stature and importance, and to-day it is probably true to say that the knowledge about cast iron within this organisation is unsurpassed by any other single body. It has contributed largely to the progress achieved with cast iron in the past 25 years and it is fitting that, at a jubilee meeting, recently held in London, further progress should be recorded by the development of iron, in the as-cast condition, having a structure of nodular form instead of the familiar elongated flake structure. This Association, under the direction of Mr. J. G. Pearce, has proved itself to be a live force and it seeks a levy on the ironfounding industry to provide the necessary funds for advances which will further raise the status of cast iron as a structural material.

INCORPORATED in June, 1921, the British Cast Iron Association associated two anniversaries with its annual meeting recently held at the Connaught Rooms, London: the silver jubilee of the Association, and the coming of age of Mr. J. G. Pearce as Director. This Association was instituted at a time when the morale of the iron founding industry was very low, as a result of a severe slump following the 1914-18 war, and it is not surprising that during the first few years of its existence formidable difficulties were encountered. After 1924, however, when the first laboratory was opened, signs of progress became more apparent. Mr. Pearce actually took charge of the laboratory in 1924, but his appointment as Director was not confirmed until 1925, since then the work of the Association has grown steadily and sound foundations for future progress have been laid.

In 1927 the headquarters of the Association were housed in St. Paul's Square, Birmingham; these were enlarged three times to provide better facilities for its gradual development. In 1942, however, the headquarters were moved to Bordesley Hall at Alvechurch where considerable progress has been made in modifying and equipping the premises to enable work to proceed on the scale desired.

The aims of the Association, as briefly given by Dr. Harold Hartley in his Presidential Address, are to find means of improving the quality, of facilitating the manufacture, and of extending the uses of cast iron. This object is sought by co-operation between the staffs of the member firms and the specialists it employs, and without the help of its industrial supporters—he was not then referring to financial help—it must languish. However brilliant the Director and his staff, they need to be stimulated by contact with the heads and staffs of the subscribing member organisations. No manufacturing concern is pulling its weight if it is content merely to give financial help by paying its due subscription—the real responsibility for the efficacy of the Association lies with the members, and they must interest themselves in its work by adding to the pool of knowledge, by serving on Committees, or by other direct and personal contact with the organisation. There is more knowledge about cast iron within the four walls of Bordesley Hall than is possessed by any other single body; this knowledge will be given to members for the asking and the best method of getting it is by personal contact.

During the past twenty-five years the technique of iron founding has altered very considerably and in this development the Association has played no mean part. Up to the first world war cast iron with a tensile strength of 15-18 tons/sq. in. was exceptionally good. To-day the material is commercially available with a tensile strength of 30 tons/sq. in. and even higher. Industry has now available a variety of types of cast irons evolved to suit special requirements such as heat resistance, corrosion resistance and wear resistance. The foundry techniques of melting, moulding and casting have been much improved and many problems connected with continuous casting in green sand and permanent moulds with mechanised plant have been overcome. The working conditions in foundries still need attention and the sections of the industry concerned will need to tackle the matter seriously if they are to continue to attract the man-power required. The industry will doubtless, in due course, have a lead from the Garrett Committee of the Ministry of Labour.

The Research Association stands midway between the universities and industry. It does not undertake fundamental research in the real sense of the phrase, although it is concerned with investigations into the underlying factors which control the behaviour of the metal and its alloys under all practical conditions.

But, if the means are available, it is desirable never to be content with the "how," rather always to strive to learn "why." Dr. Hartley stated that for many years investigations have proceeded in the research department to learn how molten iron crystallises, to determine the influence of the various ingredients and to find out why things happen as they do. In 1936 the Association made public a method showing how a fine graphite structure might be produced from a titaniferous iron. The main research has been continued and is now yielding a remarkable return. The results are still in the confidential stage although certain Provisional Patents have been filed, but in the Laboratory 20 to 30-ton tensile cast irons can be produced by casting an ordinary straightforward hematite pig iron suitably treated.

New Material

Iron, as cast, is being successfully produced with a graphite structure of nodular or spherical form instead of being in the stringy, elongated flake structure usually found in grey cast iron. This nodular graphite structure

resembles the temper-carbon form of graphite found in malleable cast-iron, after the lengthy annealing of a white iron casting (the only way hitherto known of producing it), but this new material does not possess the properties of malleable cast iron, which can be subjected to considerable deformation and distortion prior to fracture. Nevertheless, it has a small measurable elongation, 1 to 2% with the higher carbon and 2 to 3% with the lower carbon contents.

In a melt of hematite pig iron of 3.9% carbon and 2.6% silicon, a standard 0.875-in. test bar gave in the untreated and treated states respectively, tensile strengths of 15.5 and 26.5 tons/sq. in. tensile, and 29.4 and 47.9 tons/sq. in. transverse. The treatment increased shock resistance from 13 to 47 ft. lbs. and the Brinell hardness from 185 to 215.

The most significant feature of this new development is that it is applicable and indeed most readily applicable to the medium and high as distinct from the low carbon and silicon irons, that is, to the irons most easily castable and which are least subject to shrinkage in casting, as well as being the most readily machinable.

The material possesses the properties of the present high-duty cast irons without their special compositions or treatments, and yet remains readily castable and machinable. This does not mean that it will supplant high-duty irons; but rather that it will be used as a base for producing high-duty cast irons the properties of which will no longer be determined by the flake graphite structure. The same remarks apply to the special duty cast irons, austenitic, martensitic, high-silicon, high chromium, etc., used for heat and corrosion resistance, or for other special properties. Thus a Ni-resist cast iron in the untreated condition had a tensile strength of 10 tons/sq. in. and a shock resistance of 30 ft. lbs. (usual figures for a commercial material). In the treated state it had a tensile strength of 20-25 tons/sq. in. and a shock resistance of 120 ft. lbs. The deflection in transverse on identical bars of Nicrosilal was 0.75-in. and 3.5-in., respectively for untreated and treated material.

Another feature of the treated material is its uniformity in properties from piece to piece. Thus of a hundred bars cast from a 4% carbon hematite pig iron, ten chosen at random showed tensile strengths between 23.8 and 24.3 tons/sq. in. while the Brinell hardness varied only between 198 and 203. No bar tested showed any flaw. As compared with the same material in the untreated state strength, deflection and shock resistance are doubled or even trebled.

The process can be used successfully on cupola-melted irons, but much work has to be done on the founding, physical and mechanical properties before it can be applied in the industry, which itself will be a formidable task. At least a dozen investigations have to be carried out. The manner of financing the considerable expenditure involved is causing much concern to the Executive Committee and Council. It is most important to establish British priority in this field, and the technique cannot yet be disclosed, in part because the patent situation is not yet clear and in part because of problems relative to the supply of materials involved.

The evolution of this virtually new material will not only put ordinary castings into a new class mechanically, and doubtless with respect to heat and corrosion resistance and provide a new basis for the development of high-duty and special cast irons, but it will involve a

new approach to the design of iron castings and will undoubtedly influence every branch of the industry.

Additional Funds Needed

Were unlimited funds available, rapid exploration would be possible of the various fields for the application of this new knowledge, which must ultimately affect the activities of every branch of the industry. In the first instance arrangements are in hand to make field tests on the high-duty irons such as are used by the motor industry and some other sections. To permit of effective liaison between the laboratories and the section of the industry concerned, it is intended that a few selected foundries with competent technical staffs shall carry out production trials. Care must be taken to see that the development is well planned. Every endeavour will be made to render the experiment self-supporting as quickly as possible, but the work necessary, if the project is to be brought to fruition without undue delay may involve considerable expenditure.

In addition, money has to be found for more buildings. An additional 6,000 sq. ft. of space is wanted urgently for an improved chemical laboratory, a sands and refractories laboratory, a machine shop and a staff canteen. In the past, capital expenditure has been met largely by savings from current income, but if the capital expenditure needed in the immediate future cannot be met out of income, then the Council may have to contemplate the raising of a loan.

The Association has been well supported by its members and Dr. Hartley welcomed the opportunity of saying how much the Council appreciates the reception given to the proposals made a year ago that the subscription basis should be re-arranged with a view to providing a larger income. With the generous support received from the Department of Scientific and Industrial Research there is envisaged on the present basis a gross income of £50,000 a year within the next few years. The Council has it in mind that means may have to be found to enable the yearly income to be increased to £100,000.

Except for some sectional interest, it is not contemplated that existing members shall be asked to find more money, while others in the industry who must benefit from the Association's activities do not for one reason or other subscribe directly to the work. Consideration is being given to the desirability of obtaining the financial backing by means of a properly organised levy throughout the trade. It is understood that a levy less than the present subscription basis would, with the aid of the D.S.I.R., enable the desired figure to be attained. The industry is much better organised to finance a Research Organisation than was the case before the war. Now there exists the Council of Ironfounders' Associations, the Council of Iron Producers and, embracing both, the Joint Iron Council, and consultations on ways and means are in progress with these bodies.

It is hoped that the iron founding industry will take speedy action to enable development to proceed on a scale big enough to allow this new material to be applied in industry without unnecessary delay. It is certain that in a few years competition will be keen, and it is important that British iron founding should be adequately provided with technical information to enable it to meet this competition successfully. This can be done by assisting the Association to maintain its position as the pre-eminent authority on the technology of cast

iron. This new development provides an opportunity for progress and expansion which can only be obtained by intensifying its further research. The results will affect practically every branch of the ironfounding industry and a levy is an equitable method of providing the necessary funds.

Presentation to Mr. J. G. Pearce

It is noteworthy that the coming of age of Mr. Pearce as Director and Secretary of the Association should coincide with its silver jubilee anniversary. At the Association's functions held from time to time Mr. Pearce is usually in the background; on this occasion,

however, his valued services in guiding the Association in such fruitful channels were given special recognition. Mr. P. H. Wilson, O.B.E., chairman of the Council, in a few well-chosen words spoke of the great debt the Association owed Mr. Pearce for his work during the 21 years of his service and asked him to accept a silver salver as a token of the Council's appreciation and regard. The silver salver, suitably inscribed, was accompanied by a wallet containing, as Mr. Wilson said, sufficient to purchase a set of silver articles to be used with the salver. Mr. Pearce in accepting the present thanked the Council and members for their support.

Some Recent Appointments

MR. JOHN VICKERS, formerly Foundry Manager of Rolls Royce, Ltd., Hillington, Glasgow, and latterly director and general manager of Renfrew Foundries, Ltd., has now severed his connection with Renfrew Foundries, Ltd.

MR. L. R. BARRETT has been appointed lecturer in refractories at the Imperial College of Science of Technology in the Department of Chemical Engineering and Applied Chemistry. He succeeds Mr. Walter C. Hancock, B.A., F.R.I.C., who had occupied the position from February, 1914. Since 1937, Mr. Barrett has been engaged on research work for the British Refractories Research Association.

MR. A. D. STORKE AND MR. CARL M. LEOB, JUNR. have been appointed to the Board of Directors of Climax Molybdenum Company of Europe, Ltd. Mr. Storke, who is President of Climax Molybdenum Company, New York, has been elected chairman of the Board.

MR. T. H. SKELTON has retired from the position as manager of the electric melting and Tropenae steel converting and foundry heat-treatment departments of Edgar Allen & Co. Ltd. He is succeeded by Mr. W. H. Everard, who has been with Mr. Skelton for 32 years, but Mr. Skelton's experience will continue to be available in a consultative capacity.

MR. S. W. WEST, of the X-ray Division of Philips' Lamps, Ltd., has left London by American Overseas Airways for the United States of America. It has been announced that he will join the North American Philips Company as technical manager X-ray Division, in the New York office. Mr. West, in conjunction with Philips' Lamps, Ltd., holds a number of patents in the field of X-ray science. In 1940, to meet the urgent need for X-ray inspection in war industries, he originated a system of factory-planned X-ray protection by prefabricated units which could be erected rapidly without expert supervision, making use of home-produced substitute for metallic bed.

MR. ARTHUR FISHER, formerly in the metallurgical department of Magnesium Elektron, Ltd., has taken up an appointment as research officer at Messrs. Vickers-Armstrong, Ltd., Barrow-in-Furness. A Research Association has been formed by the Admiralty between several of the large gear machinery firms and Messrs. David Brown & Sons (Huddersfield), Ltd., and Mr. Fisher is acting as co-ordinator.

MR. HAROLD V. SHELTON has been appointed deputy chairman of the Bristol Ironfounders' Association which is concerned with the commercial co-ordination and development of that industry. Since 1933 he has been general manager of the Light Castings Department of Messrs. Newton Chambers & Co. Ltd.

MR. J. TOWNS ROBINSON has joined the staff of Southern Forge, Ltd., of Langley, as technical superintendent. Mr. Robinson started as a qualified chemist with Consett Iron Co. 35 years ago and later was chief metallurgist with various companies. He was responsible for development work with the London General Omnibus Co. and the A.E. Co. at Walthamstow. In 1925 he joined Col. W. C. Cevereux at Peter Hooker, Ltd. and co-operated with him in pioneering early development of aluminium alloys. On the formation of High Luty Alloys, Ltd. he was appointed chief metallurgist and became technical superintendent in 1938; it is this position he has resigned to take up the new appointment. Mr. Towns Robinson has contributed many articles to the technical press on the science and technology of light metals and alloys, some of which have been published in this journal.

MR. L. S. KINNEAR has been appointed managing director of the British Oxygen Co. Ltd.

MR. L. B. ROBINSON has been appointed managing director of the Zinc Corporation jointly with Mr. W. S. Robinson, and managing director of New Broken Hill Consolidated. He has resigned his position as joint managing director of the Imperial Smelting Corporation.

MR. L. H. MAIDMAN, secretary of Specialloid, Ltd., has been appointed to the Board of the Company. He is also a director of Specialloid (Canada), Ltd.

MR. C. F. BAREFORD has been appointed manager and head of the new Mullard Electronics Research Laboratory at Cross Oak Lane, Salfords, near Horley in Surrey. He took a first-class honours B.Sc., in physics in 1930; a year later he was awarded the M.Sc. degree, and in 1933 a Ph.D. degree for work on the spot discharge in vacuo. He worked in this field until 1934, when he joined the B.T.H. Company as a vacuum physicist. In 1936 he went to the Royal Naval Signals School at Portsmouth, which later became the Admiralty Signals Establishment. He has joined the Mullard Radio Valve Company direct from the Admiralty, and now he will be closely connected with the development of electronics as applied to industry.

Mr. G. R. L. WATKINS, A.M.I.N.A., has been appointed to the staff of the Aluminium Development Association as naval architect. Trained at Armstrong Whitworth's, Newcastle-on-Tyne, Mr. Watkins spent several years in Spain with La Sociedad de Construcción Naval, Ferrol, and for the past ten years has been on the design staff of Cammell Laird, Birkenhead.

Mr. J. C. BAILEY, B.Sc., who has been acting as information officer on the staff of Aluminium Development Association for the past 12 months has now been appointed liaison officer to co-ordinate the work of the technical committees and senior technical staff. For some years Mr. Bailey was on the research staff of I.C.I. Metals, Ltd. Prior to the war he was with Murex Welding Processes, Ltd.

Mr. N. B. VAUGHAN, M.Sc. has been appointed information officer and librarian to Aluminium Development Association. For the past seven years he acted as editor of publications of the Institute of Metals in the absence (on military service) of Col. Guilan.

Mr. F. L. STAFFORD, A.M.I.Mech.E., M.I.Loco.E., who until recently was chief mechanical engineer to the Paraguay Central Railway has been appointed Railway Transport Engineer to the Aluminium Development Association.

Mr. R. B. HEYWOOD, B.Sc., who until recently was responsible for the photoelastic department at Messrs. Rolls-Royce, Ltd., is now a consultant on photoelastic and stress problems. His address is 37, Bass Street, Derby.

Mr. CHARLES MESLING, Senior Industrial Liaison Officer of the Council of Industrial Design has resigned the appointment to join Messrs. Allen-Bowden, Ltd., Industrial Designers and Consulting Engineers of Leamington Spa, as general manager. He will operate from the London Offices of Messrs. Allen-Bowden, Ltd., at 4, Lygon Place, S.W. 1. Telephone: Sloane 7291.

Mr. F. A. Fox, M.Sc., F.I.M., is relinquishing his appointment as chief metallurgist of Magnesium Elektron Limited and is joining the British Welding Research Association as Assistant Director of Research. He will be mainly concerned with the metallurgical activities of the Association and, in particular, with the light alloy side. He is taking up his new appointment at the beginning of January, 1947.

His successor as chief metallurgist of Magnesium Elektron Limited is Captain A. C. Jessup.

Mr. J. H. BUTLER has been appointed chief engineer to the Stanton Ironworks Co. Ltd. He has resigned a similar position, which he held for many years, with Consett Iron Co. Ltd. to take up his new appointment.

Electron Jubilee Celebrations

THE fiftieth anniversary of the discovery of the electron by the British physicist, Sir Joseph Thomson, O.M. will occur next year. To mark this jubilee and to demonstrate the tremendous influence such an advance in pure physics may have on the life of the community, the Institute of Physics and the Physical Society are jointly arranging a series of meetings and other functions to take place on September 25th and 26th, 1947, in London. A special exhibition which will remain open to the public for several weeks, will be held at the Science Museum, South Kensington.

Industrial Project for Eaglescliffe

THE policy of the Government is to secure a balanced distribution of industry over the nation as a whole, and to redress this balance especially in the Development Areas which need new industries. The manufacture of automotive vehicles in particular is at present almost wholly confined to areas of industrial congestion. It has long been the desire of the Government to secure from this industry some substantial contribution toward the need of the Development Areas. Morris Motors, Ltd. has already demonstrated its willingness to assist by establishing successfully during the war a factory at Llanelli for the manufacture of aircraft parts, which is to continue permanently in the post-war period as a productive unit for automobile components.

In pursuance of this policy, the organisation now proposes to establish a new productive unit in the North-Eastern Development Area at the Government factory at Eaglescliffe, Co. Durham. This factory is at present being operated, on a diminishing scale, by the company (as agents for the Ministry of Supply) as a Metal Recovery Depot for reclaiming metal alloys from crashed aircraft. The Board of Trade, in collaboration with other Departments concerned, has agreed to allocate this factory to the Morris Motors Ltd., and negotiations are proceeding forthwith.

It is proposed to establish at this factory, on an expanding scale, an assembly plant, and later a full-scale machine and productive unit for the manufacture of automotive vehicles. A beginning is being made with agricultural tractors, of which prototypes are now undergoing tests and field trials. Thereafter will follow production of specialised agricultural implements and parts for tractors. Production of military vehicles is also contemplated at a later stage.

World List of Scientific Periodicals

ACTIVE preparations are being made for the issue of a third edition of the *World List of Scientific Periodicals*. It contains upwards of 33,000 titles of journals and includes the holdings of some 180 libraries in Great Britain and Ireland. The new edition, which is designed to include all the scientific and technical periodicals that appeared during the period 1900-47 as well as the holdings of additional libraries, will therefore be considerably larger. Librarians are being asked to co-operate as before by sending particulars of all those journals on their shelves that do not appear in the second edition or are shown there as having no location in this country, to: The Secretary, World List of Scientific Periodicals, c/o The Zoological Society of London, Regent's Park, London, N.W. 8, from which office further information may be obtained.

THE directors of McKechnie Bros., Ltd. have honoured two old servants of the firm, Mr. J. A. Bower with 60 years' service and Mr. J. L. Morewood with 51 years' service. Each was the recipient of a cheque from the Company, while from the senior staff Mr. Bower received a clock and treasury notes and Mr. Morewood a silver salver. The presentations were made at a complimentary dinner given in Birmingham by the directors over which Mr. J. Rae, chairman of the Company presided. Both Mr. Bower and Mr. Morewood are well-known personalities in the non-ferrous metals industry.

Some Aspects in the Development of Alloy Steels

By L. Rotherham, M.Sc., F.Inst.P.

Brown-Firth Research Laboratories

There is a tendency towards a return to the use of higher alloy types of steel to ensure a more uniform and reliable heat-treated product, but, for economic reasons, austerity will continue to be applied in the use of alloying elements. Considerable advances, however, have been made and this brief outline indicates some of the directions in which alloy steels have been developed during and since the war, the main purpose of which is to show that our understanding of basic phenomena has advanced. With the continued application of research and control further remarkable advances can be expected.

Introduction

AT the present time, there is no need to emphasise that the aftermath of war has left many economic problems, which foreshadow difficulties in peacetime production which will be comparable in magnitude with those which were surmounted with great success during the war. Although alloying elements are more available, we are not readily able to provide the finance for their purchase, and in any case since production costs are inevitably higher than pre-war, it is as essential now, as during the war years, that continued economy in alloying elements should be practised, so that costs may be kept at a reasonable level.

It is important, therefore, to bear in mind the experience of the wartime years, especially in respect of methods of alloy conservation, and the utilisation of the alloying elements which are present to a considerable extent in present-day alloy steel scrap.

Alloy Conservation

The present time sees a tendency for a return to the higher alloy types of structural steels and rolled products. In many cases the reason is quite simple and is due to the fact that most alloy and special steel manufacturers have a high reputation to maintain, and with the possibility of heat-treatment errors reduced in many cases by use of alloy additions, a more uniform and reliable product is assured by the increased use of such additions. Here the work of the Technical Advisory Committee in wartime should be remembered, and, in particular, attention should be paid to the careful study and experimental work on which its conclusions were reached.

This Committee consisted of representatives of most of the better known steel makers, in combination with representatives of user interests, and, with the facilities of the organisations they represented, offered a wealth of experience and laboratory strength which would be difficult to match. The first task was to review existing specifications for different classes of steel. It was immediately clear that much duplication and overlapping existed, and that different suppliers might offer a wide variety of alloy types for essentially the same purpose. In fact it was found that the steel trade was working to a very large number of specifications which were reduced to 85 categories in the T.A.C. Schedule. These were finally reduced to the form of a British-Standard Specification, and the steels of this now well known En series may be assumed to have come to stay for a long time.

This relatively short list of specifications, of course, includes many steels of a fairly high alloy content, and the use of over-alloyed types is still possible. The late Dr. W. H. Hatfield, F.R.S., drew up a table of materials for use in the range of tensile strength from 35/40 tons/sq. in. to 100 tons/sq. in., for rolled products up to 6 in. dia. This data is reproduced in the accompanying table.

It will be noted that only seven materials are listed and that nearly one half of the table is made up of carbon steels and carbon-manganese steels. This table will find very much support in many quarters, but is perhaps an over-simplification, up to a point, in that for example many useful alloys, such as the chromium-molybdenum steels and other well-known types are excluded. Furthermore, it must be recognised that,

SHORT LIST OF SPECIFICATIONS

Tensile Range Tons/sq. in.	35/40	40/45	45/50	50/60	55/65	60/70	65/75	70/80	75/90	100 min.
Size										
Up to 1½ in. dia.	1	2	2	2	3	3	3	3	4	5
1½ to 1 in. dia.	1	2	2	3	3	3	3	5	5	6
1 to 2½ in. dia.	1	2	2	3	3	3	4	5	6	6
2½ to 4 in. dia.	1	2	2	3	4	5	6	6	6	6
4 to 6 in. dia.	1	2	3	4	5	6	6	6	6	7

Steels	C	Si	Mn	Ni	Cr	Mo	Heat-treatment
1	0.30/0.35	0.35 max.	0.70/0.80	—	—	—	Normalised and oil hardened.
2	0.40/0.45	0.35 max.	0.70/0.80	—	—	—	Normalised and oil hardened.
3	0.35/0.45	0.35 max.	1.60/1.80	—	—	—	Oil hardened and water hardened.
4	0.35/0.42	0.35 max.	1.60/1.80	—	—	0.30 max.	Oil hardened and water hardened.
5	0.40/0.45	0.35 max.	0.50/0.60	1.5/1.6	1.00/1.25	0.25/0.30	Oil hardened.
6	0.36/0.44	0.35 max.	0.60/0.70	2.5/3.5	0.50/0.80	0.50/0.70	Oil hardened.
7	0.30/0.35	0.35 max.	0.40/0.50	4.0/4.5	1.25/1.50	0.30/0.30	Oil hardened.

even with the most modern plant, some steels are intrinsically more difficult to produce as satisfactory ingots than others so that melting costs on some low-alloy types may be greater than others of a rather higher alloy type. Since fuel economy is equally important with alloy conservation, consideration must be given to both points in selecting the most suitable material for a particular purpose.

Similar considerations apply to heat-treatment. For instance, the table suggests the extended use of carbon and carbon-manganese steels in the heat-treated condition, but in many cases similar properties can be obtained in higher alloyed types either without any heat-treatment or with a simplified heat-treatment. It follows, therefore, that cases will arise where the use of higher alloyed types would be justified on economical grounds.

The table given above may, therefore, be seriously overstating the case when considered against present condition, although it may well have been suited to wartime requirements. On the other hand, the fundamental conception on which it is based is that fitness for purpose is best demonstrated by the properties achieved, bearing in mind all properties, rather than on the presence of a particular alloy addition. This thesis can hardly be questioned.

Heat-treatment

Bearing in mind that heat-treatment operations are more readily controlled when certain alloy additions are used, it follows that economy in their use must necessarily increase the variability of the product, unless at the same time an increase in our knowledge and understanding of heat-treatment phenomena is achieved. It is obvious that a responsible body such as the T.A.C. would itself carry out sufficient experimental work to justify its recommendations, and this provides a most useful background to the En series of steels. The procedure adopted in the work of the T.A.C. was to examine the properties obtained by the heat-treatment of bars of different ruling sections.

A similar series of steel types to the En steels was evolved in the U.S.A., the N.E. steels, and the procedure in this case was based on the Jominy or end-quench hardenability test. This procedure is perhaps speedier than that adopted in Britain, but its results are less sure. It has aroused considerable interest, and a study of this, and of other questions of hardenability, has been made by the Hardenability Sub-committee of the T.A.C. The publication of the report of this committee is now awaited, and it will doubtless assist in the interpretation of Jominy test results.

Welding of Alloy Steels

The greatest weight of material used for welding is, of course, mild steel, so that in most cases, dangers of cracking arising from the rapid cooling from the austenitic range does not generally arise. The production of fighting vehicles during the war was a different matter, however, since the high hardenability of the materials used for armour introduces a serious risk of cracking. This difficulty was met by the controlled use of austenitic materials of the 25% chromium, 20% nickel, or 18/8/Mo types in the weld metal, and the pre-treatment or post-treatment of the welds. Furthermore, the selection of suitable alloying elements to give the required hardenability rather than the use of higher carbon contents, assisted in the solution of the problem.

Attention has also been given to the control of gas content of the welds. Careful study has demonstrated that hydrogen can have a very marked influence on the properties of steel, particularly on the ductility, and nitrogen and oxygen can be very undesirable also. The elimination of these elements by control of the slag-covering of the molten weld metal and the use of the welding rod coatings which are low in moisture or other hydrogen-bearing compounds has been very successful.

Machinability

Attention to the machining qualities of alloy steels has been continuous, and the progress steady for some years. Generally speaking, it is now true to say that most of the special and alloy steels which from time to time have been regarded as difficult to machine, have now been produced in types which are much more readily machined. In effect, a whole series of what may be regarded as new alloy steels are now produced with additions of one or more of the elements lead, sulphur, molybdenum, zirconium or copper.

The reason for the marked influence of these elements, singly or in combination, on machinability is not clear, but the effect on production rates can be quite remarkable. To some extent the production of these types of alloy steels is still rather specialised, particularly in the case of special steels of say the stainless and heat-resisting types. For some alloy types a satisfactory solution of the machining difficulties has not yet been reached, but the problem is receiving continuing attention.

The cutting tools themselves received a good deal of attention in war-time, and substitute materials for the 18% tungsten types of high-speed steels were devised. The substitute alloys are less used at the present time, for reasons similar to those which explain the tendency to revert to higher alloyed types of structural and rolled products.

On the other hand, the hard carbide alloys which were developed for a much wider variety of uses in war-time than pre-war can still offer the types which were successfully applied in war-time use. A range of both tougher and harder materials, better than at any previous time, is now available, and the uses of powder metallurgy continue to expand.

High-temperature Alloys

Wide publicity has rightly been given to the pioneer work of British engineers in the production of the gas turbine, and the engineers in their accounts of the development have generously acknowledged the assistance they have received from the metallurgist. The early work at the Royal Aircraft Establishment and at Power Jets, Ltd., was to some extent limited by the materials available, and at the present time the designers still ask for better materials to withstand ever higher temperatures and high stresses in the blades and discs of the gas turbine. It is clear, therefore, that the spectacular improvements of the past few years may be matched by those of the future.

The early development of the Whittle gas turbine, was based very largely on materials then available which were not expected to withstand the higher temperatures which were expected to be encountered later in the development. Such a material was the "Stayblade" alloy of Firth-Vickers Stainless Steels, Ltd., which is a material of the 18% chromium, 8%

nickel type, with properties which while superior to those of others of the same class of steel at temperatures up to about 550° C. were not substantially better at the temperatures of main interest—i.e., 650° C. and upwards.

Fortunately, in the early days of the war a new alloy Rex 78, which may perhaps be considered the first of what has been described in the United States as "Super-alloys," became available. As a rough comparison, this material, with 18% nickel, 14% chromium, 4% molybdenum, 4% copper, 0.6% titanium, and a low carbon content, with the remainder iron, can carry the same load as the "Stayblade" alloy at 100° C. higher temperature. A comparison of the two materials on the basis of the time yield test is shown in Fig. 1, taken from a paper by Dr. T. A. Taylor :—*

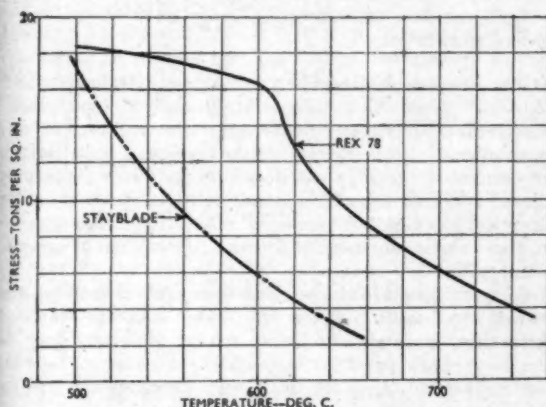


Fig. 1.—Stress-temperature curves for Stayblade and Rex 78:

Plotted stress is the Hatfield "time-yield" value, i.e., the stress producing a rate of creep not exceeding 10^{-3} in. per in. per hr. between the 24th and 27th hours.

This alloy, Rex 78, was important in that it had properties sufficiently good to permit the further development of the engines, and it demonstrated that good creep resistance could be developed in alloys of the precipitation hardening type. Research on these alloys and others based on nickel and cobalt alloy series has been intense. The nickel chromium based alloys of the "Nimonic" type have been used extensively in this country, while in the United States the greatest advances have been achieved in the cobalt-based alloys.

The best alloys now available show a considerable advance on the "Nimonic 80" alloy of the Mond Nickel Company, which has been used successfully for the turbine blades in the British aircraft gas turbines. As a rough indication of the progress made, the curve for the time-yield values of alloys now available falls somewhat similarly to that of Rex 78 as shown in Fig. 1, but along a line displaced 100° C. higher than that shown for Rex 78. The result then of about ten years' effort is an increase in working temperature of about 200° C.

The effects of the precipitation process in these alloys on the result of the creep tests are not fully understood. In some of the alloys, the precipitation process itself is simple and well understood, while in others it is extremely complicated. In general, one of the elements molybdenum, tungsten, titanium or columbium has been found to give a suitable precipitation process. It has

been suggested that alloys of the higher melting point elements—e.g., chromium, will permit a still further step forward, and research on these lines will no doubt be continued. It is clear that the metallurgy of these alloys is very different from that of normal alloy steels.

Castings

An interesting development is the very extensive use made in America of the precision-casting technique, a process which has been described in the literature and need not be referred to in detail here. It has been suggested that this is a modification of a very ancient process, and this may be so, but the production of millions of turbine blades as castings is a new process and a revolutionary one at that. More developments in this direction can be expected.

However, a considerably greater weight of special alloy castings was made during the war years by a specialised process of centrifugal casting, and the use of this process for the production of sleeves for sleeve valve aero-engines was on a very extensive scale. The development of alloys combining a high-fatigue resistance in the castings with a high coefficient of expansion was very important.

Castings of alloy steels have found increased use in aircraft applications, and cast armour was used to a considerable extent to replace fabricated structures of armour plate. It would appear that the range of usefulness of castings as opposed to forgings has been extended by experiences of the past few years, although forgings still retain many obvious advantages.

Conclusions

This brief review is insufficient to give more than an outline of the development of alloy steels during the war and since. Other examples could be quoted, such as the production of forgeable permanent magnet alloys, comparable in performance with the best cast alloys, which, themselves have about three times the energy content of the very good alloys available commercially before the war. Similarly, in dealing with heat-resisting alloys, nothing has been said of the developments of low alloy materials.

The main purpose of this short report, however, is not to collect every case where improved materials are now available, but rather to present a quick overall sketch of the present situation, which will be sufficient to indicate how our understanding of basic phenomena has advanced. There is no doubt that such an advance has been made, although many empirical results are far from being understood at present. With the continued application of research and technical control, further remarkable advances can be expected in the next few years.

Medal and Prize for Welding Expert

THE Council of the Institute of Welding have conferred the Sir William J. Larke medal and a prize of £50 upon Dr. H. Gottfeldt, M.Inst.W., for a paper entitled Welded Drag Line Booms of 150 ft. length. Dr. Gottfeldt is assistant to Mr. C. Helsby, consulting engineer, and the prize paper describes the fabrication of welded drag line booms for use in open cast coal workings. It will be read at a meeting of the Institute in London on October 31.

* "Recent Developments in Materials for Gas Turbines," *Proc. Inst. Mech. Eng.*, 1945, 152, pp. 409-512. (War Emergency issue No. 12).

Copper and Copper Alloys

A Survey of Technical Progress During 1946

By E. Voce, Ph.D., M.Sc., F.I.M.,

Copper Development Association

Progress in the development and uses of copper and its alloys has been continuous for centuries and, as this survey reveals, the urge to improve these materials, for the better service of mankind, persists and, despite the difficulty in trying to meet the heavy demands for semi-finished products in copper and its alloys, recent progress has been considerable. Here the author discusses the production of copper and its up-grading by distillation; the casting and properties of a number of copper alloys; corrosion and oxidation and some aspects of physical metallurgy.

THOUGH a great many papers of first-rate importance to the metallurgy of copper and its alloys have been published during 1946, the year seems, on the whole, to have marked a relatively quiescent period in respect of major technological developments, such for instance as continuous casting processes which were very much "in the news" in 1945. In Britain, and indeed throughout the world, the copper industry is working to the limit of its capacity in an attempt to meet the huge demand for semi-finished products essential to peace-time reconstruction; manufacturers are embarrassed by the volume of the orders they receive, and deliveries inevitably tend to be tardy. One of the largest and growing demands for copper is connected with the housing drive, for copper is being very widely used for roofing, flashings and piping for both water and gas.

The Production of Copper

A comprehensive description of the Cerro de Pasco¹ mines in Peru became available in this country just too late for inclusion in last year's review, the entire issue of *Mining and Metallurgy* for November, 1945, being devoted to the subject. Every aspect of the enterprise is covered, including its commercial history, the geology of the district and the methods of mining used, with engineering, power supply and railroad details, but from the present point of view the most interesting section is that devoted to the production of copper. Methods are orthodox, and consist of roasting, reverberatory smelting to matte followed by blowing to blister copper. It is claimed that the silica arches of the reverberatory furnaces have unusually long life, mainly because the furnaces are not over-driven and because the fuel gives an adherent and protective ash. An exceptionally low grade matte, carrying little more than 16% of copper is intentionally produced. The plant includes an experimental electrolytic refinery for copper, with a view subsequently to refining the whole of the output, which amounts to about 100 tons daily.

Similar in scope is the account of the plant of the International Nickel Company² given in the *Canadian Mining Journal* for May, 1946. Special attention should be paid to Chapter VII, which deals in detail with the refining of copper. Six years of operation at the Noranda

copper smelter is described by Boggs, Anderson and Stevens,³ while McLachlan, Ames and Morton⁴ have contributed an interesting account of cyaniding at the same mines. From British Columbia comes information concerning the geology and development of the Britannia Mines⁵ while South African practice is represented by a paper⁶ on the treatment of floatation concentrates in the Transvaal, mainly for the separation of copper from gold.

Of more general interest is the account of ore concentration and milling given by Rose⁷. In the field of floatation, research has led to a new understanding of the long-chain paraffins, especially in connection with the floatation of oxide ores, and encouraging results have been obtained in the separation of copper from cobalt and from molybdenum. There is a significant trend toward the use of rod mills for fine crushing, enabling relatively small balls to be adopted for final grinding. By such practice both dust nuisance and screening costs are said to be reduced.

From a number of scattered sources the following greatly condensed picture of other technical developments and trends in the production of copper may be pieced together.

Several American firms are experimenting with the leaching of low-grade oxidised and mixed ores, and the leaching of marginal grade ores in dumps is being developed. Considerable attention is being given to the production of ferric sulphate and sulphuric acid for the purpose, and the reduction of their cost by the auto-oxidation process. The U.S. Bureau of Mines is operating a pilot plant for the production of sponge iron at low cost from Arizona ore and coal, expressly for the precipitation of cement copper.

In pyrometallurgy, progress has been made in the use of pre-heated air and forced draught in reverberatory furnaces using gas burners. At Phelps Dodge calcine smelting has been discontinued, and replaced by the smelting of wet charge. A great deal of attention has been paid to refractories, especially those used for the

¹ W. R. Boggs, J. N. Anderson and W. L. Stevens, "The Noranda (Copper) Smelter from 1939-1945," *Canad. Min. and Met. Bull.*, 1946, No. 298 (Trans. Vol. 48), 402-428.

² C. G. McLachlan, H. L. Ames and R. J. Morton, "Cyaniding at Noranda," *Canad. Min. and Met. Bull.*, 1946, No. 407 (Trans. Vol. 49), 91-120.

³ W. T. Irvine, "Geology and Development of the No. 8 Orebodies, Britannia Mines, B.C.," *Canad. Min. and Met. Bull.*, 1946, No. 407 (Trans. Vol. 49), 191-214.

⁴ D. D. Still and N. B. Locke, "The Local Treatment of Floatation Concentrates in the Transvaal, South Africa," *Jnl. Chem., Met. and Min. Soc. of S. Africa*, 1945, 41, 138-159.

⁵ B. H. Rose, "Ore Concentration and Recovery," *Mining and Metallurgy*, 1946, 27, 70-76.

¹ W. W. Fowler, J. W. Hanley, I. L. Barker and others, "The Cerro de Pasco Enterprise," *Mining and Metallurgy*, 1945, 26 (467), 507-574.

² International Nickel Co. Ltd., "The Operation and Plants of the International Nickel Co., of Canada, Ltd.," *Canadian Mining Jnl.*, 1946, 67 (whole issue).

urnace arches of reverberatory smelters, to heat insulation and, again at Phelps Dodge, to the design of the converters themselves.

Up-grading by Distillation

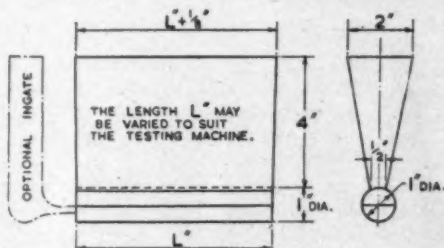
The decision of the Government to send nearly 150,000 tons of brass to be refined in America during the next year or so focusses attention on an American plant for the removal of zinc from brass and nickel-silver by distillation. A full description of the process is given by Poland⁸ of the Revere Copper and Brass Incorporated, in whose factory at Rome, N.Y., a U.S. Government-owned plant was erected. Briefly the brass or nickel-silver scrap is melted in an electric resistance furnace, from which it is run into the still. This is essentially a second electric furnace, with carbon resistance elements, working at about 1,750°-1,820° C. and connected to a condenser to receive the zinc. The atmosphere in this furnace consists almost entirely of zinc vapour. Slab zinc is cast periodically from the condenser, while the residual copper or cupro-nickel is carried molten to a converter, in which it is blown with air, skimmed and poled in a manner similar to that used in ordinary copper refining. It is claimed that the process and equipment are economical to run, and that the necessary investment is not excessive. Its main function during the war was to provide cupro-nickel for condenser tubes from the relatively abundant nickel-silver scrap, thus economising in nickel of which a shortage was anticipated. Whether or not it would prove profitable in a peace-time economy seems questionable.

Casting of Copper Alloys

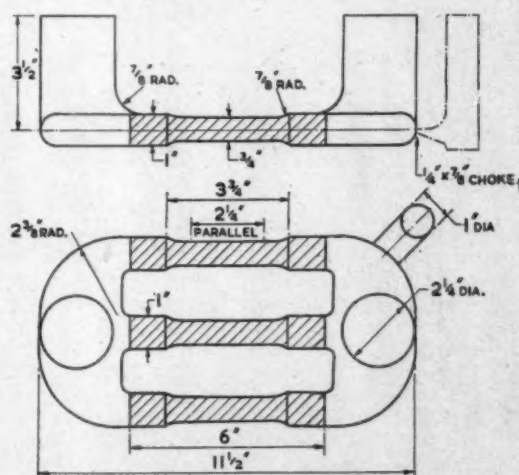
Intense activity has been shown during the year by the British Standards Institution, both in the preparation of a comprehensive schedule of copper alloy ingots and castings and in the formulation of a code of procedure for the testing and inspection of copper alloy castings. Neither of these documents has yet been finally adopted, but the schedule, which covers twenty alloys, has been issued for industrial comment.⁹ In regard to the testing code, it is no secret to say that the Institution strongly favours the use of separately cast test bars in preference to those attached to the castings themselves. The modern tendency is to regard the tensile test figures more as an indication of the quality of the metal from which the casting is made than of the properties of the casting as such, and for this reason a separately cast test bar, properly designed to reveal the gas content or other disabilities of the melt, is clearly desirable. As a result of a full investigation by Hudson¹⁰ the two types of test bar castings illustrated in the accompanying drawing have been tentatively proposed, the wedge bar being preferred for most purposes. It is interesting to note that the Americans have reached the same conclusion as to the primary function of the tensile test, and are recommending two types of separately cast test bar essentially similar to our own.¹¹

Another interesting link with America is provided by excellent interchange paper between the Institute of British Foundrymen and the American Foundrymen's Association on the subject of fluidity testing by Clark.¹²

After a critical examination of the literature, covering 105 references, Clark gives specific recommendations for the standardization of a universal fluidity test including the form and length of the flow channel, the mould material, pouring arrangements and temperature measurement. The details are beyond the scope of this review, especially as the original paper is readily accessible in this country as well as across the Atlantic.



WEDGE TEST BAR.



TEST BARS CAST TO SHAPE.

Both here and in the United States the drying of cores by dielectric heating has received considerable publicity^{13, 14}. The core to be dried is placed between two plates charged with high frequency alternating current, which generates heat simultaneously at all points within it, and drying is effected in roughly one-tenth of the time taken by the normal process of heating the core from the outside. With acceleration such as this it is clear that output can be very materially increased, especially in the routine production of cores of similar shape and size, and it is claimed that both the running and installation costs of dielectric heating equipment compare favourably with those of the more orthodox methods. Dielectric heating is best applied to core sands using synthetic resin binders, where removal of water and polymerisation of the resin can be effected quickly at moderate temperatures. Oil-bound sands necessarily require more time for oxidation and other chemical changes to take place in the oil.

An interesting development in the technique of

⁸ F. F. Poland, "Distillation of Zinc and Refining of Residual Metals from Copper-base Alloys," *Metals Tech.*, 1946, Sept., T.F. 2065.

⁹ British Standards Institution, "Comprehensive Schedule of Copper Alloy Ingots and Castings," Paper CH (NFE) 4306 (Draft for comment).

¹⁰ F. Hudson, "Standard Test Bars for the Non-ferrous Foundry," *Foundry Trade Jnl.*, 1946, 74, 185.

¹¹ G. H. Clamer, "Test Bars for 58:5:5 Alloy," *The Foundry*, 1946, 74 (9), 35 and (10), 104.

¹² E. L. Clark, "Fluidity Testing of Foundry Alloys," *Foundry Trade Jnl.*, 1946, 74, 443 and 50, 11; *American Foundryman*, 1946, 10 (1), 25.

¹³ J. R. Calhoun, L. E. Clark and H. K. Salsburg, "Drying Sand Cores," *Metal Industry*, 1946, 60 (13), 267 (From *Industrial Heating*).

¹⁴ J. McElgin, "Baking Cores Dielectrically," *The Foundry*, 1946, 74 (6), 114.

moulding is the use of heat insulating pads or inserts, as described by Taylor and Wick.¹⁵ Gypsum (plaster of Paris) provides greater heat insulation than foundry sand, and can be used in contact with molten copper alloys, though it is inadmissible for ferrous metals which tend to absorb sulphur. The possibilities of controlling the rate and direction of solidification, to improve soundness, will be apparent to the practical founder, for the judicious arrangement of chills and gypsum sleeves or pads inserted into ordinary sand moulds provides three graded rates of heat extraction. The number and volume of the risers, when insulated with gypsum can be materially reduced, representing an important economy both of material and labour.

Jazwinski and Finch¹⁶ suggest the introduction into a special closed feeder head of a capsule containing a "thermit" mixture including aluminium powder and a suitable metallic oxide, which after a short delay liberates both heat and an inert gas under pressure. The purpose of the delay, effected by the time required to melt the container of the capsule, is to permit the formation of a shell of solid metal enclosing the feeder head, so that the full pressure of the liberated gas acts upon the molten metal within it. Excellent results, in respect of soundness, are claimed for iron and steel castings and encouraging experiments have been made with copper-base alloys. Combining this idea with that of the heat-insulating pads and risers just described, the Pittsburgh Metals Purifying Co.¹⁷ have brought out a material which, after the addition of a little water, can be moulded in the same way as ordinary core sand. It can be dried and hardened at a temperature not exceeding 200° C., but on contact with molten metals at higher temperatures, glows with a strong but controllable exothermic reaction, while retaining its shape and mechanical strength. Thus the insertion of a narrow neck moulded from this material between the feeder head and the casting, will not only reduce the size of the head required by keeping the metal in it thoroughly hot, but also minimise the labour of fettling.

To founders who may have been troubled by surface defects on bronze castings made in synthetically moulded sands, the investigations of Morey and Kattus¹⁸ will be of immediate practical value. Fins or veins sometimes protrude from the metal, which may penetrate for considerable distances between the grains of the sand. Such defects are rarely found when natural sands are used. Comparative experiments with refractories other than sand, established that the cracking of the mould, which permits penetration of the molten metal, is connected with volume changes occurring at the transformation of alpha into beta quartz at 573° C. Proper degassing of the melt does much to mitigate the trouble by reducing the exudation of tin-sweat at low temperatures. Other recommendations include the application of a mould wash of a flux such as sodium carbonate or of silica flour. A fine sand of wide grain size distribution should be used, containing as little organic binder as possible.

Continuing his researches on the casting of bronzes,

15 H. W. Taylor and W. C. Wick, "Use of Heat-insulating Pads and Riser Sleeves for Producing Sound Bronze Castings," *The Foundry*, 1946, 78 (10), 88 and (11), 107.

16 R. T. Jazwinski and S. L. Finch, "High-pressure Feeding of Static Moulds," *Iron Age*, 1946, 157 (Jan. 10), 59.

17 T. B. Lloyd, "Thermotomic—A New Feeding Technique for Castings," *Iron Age*, 1946, 157 (Apr. 25), 62.

18 B. E. Morey and J. B. Kattus, "Preventing Veining and Penetration on Castings made in Synthetic Sands," *American Foundryman*, 1946, 19 (5), 55.

Pell-Walpole¹⁹ has found that a thoroughly degassed melt may be spoiled by contact with moisture whether from green-sand moulds, from refractory-lined pouring bowls or from sand thrown on the surface of the melt to thicken the degassing flux before skimming. A systematic investigation of the factors controlling the incidence and extent of this reaction was made, and it was found that sea sand bonded with an oil-cereal agent and baked at 200° C. gave minimum gassing. When a choice of metal is possible the phosphorus content should not exceed 0.25%, with the smallest amount of tin and zinc and the largest amount of lead consistent with the required properties. In the chill casting of bronzes Pell-Walpole²⁰ finds that freedom from the most harmful types of shrinkage porosity is obtained when the pouring rate is the slowest at which the mould can be filled without cold shuts. Other things being equal, the critical pouring rate is proportional to the periphery of the cross section of the mould. In still another publication Pell-Walpole²¹ traces the relationship between porosity and tensile properties of chill and sand-cast bronzes, showing that porosity has the effect of reducing the extent to which the specimen may be deformed before fracture, without altering the intrinsic tensile properties of the material of which it is composed.

An account of a visit to American foundries is given by Skript.²² On the whole he found that practice was much like our own, but in one shop making small brass castings melting was done in a cupola at the rate of about 1 ton per hour. Prices for machine moulded castings were reasonable, but hand moulded work and skilled labour such as pattern making were very costly.

The physical chemistry of slags and fluxes, with special reference to the production of copper, is outlined by Lepp in a series of four important articles.²³ After tracing the early history of the extraction of metals from ores and of the use of fluxes in remelting them to form alloys, the author describes the rapid strides made in comparatively recent times, and goes on to develop the thermodynamic principles involved in the removal of sulphur from iron and copper. The principles and calculations involved are illustrated by a detailed description of the desulphurisation of copper by basic slags, and it is claimed that very good practical results are obtained by the use of barium carbonate for this purpose. He points out that it is not the amount of heat liberated by the reaction, but the change in free energy, which gives a measure of the affinity of the various elements one for another, and indicates the direction in which the reaction will proceed at a given temperature.

Properties of Copper Alloys

Copper Nickel Manganese Alloys.—Quite the most spectacular recent event on the history of copper base alloys is the exploration of the copper-nickel-manganese system in a prolonged series of researches from 1941 onwards by R. S. Dean and his collaborators at the United States Bureau of Mines, culminating in the development of a new series of alloys capable of heat-

19 W. T. Pell-Walpole, "The Gassing of Bronzes by Reaction with Moulding and Core Sands," *Foundry Trade Jnl.*, 1946, 78, 87, 147, 163, 209 and 235.

20 W. T. Pell-Walpole, "Control of Shrinkage Porosity and Mechanical Properties in Chill-cast Phosphor-Bronze, Lead-Bronze and Gun Metals," *Metallurgia*, 1946, 34 (200), 85 and (201), 1, 5.

21 W. T. Pell-Walpole, "Chill-cast Bronzes, the Relation Between Porosity and Tensile Properties," *Metal Industry*, 1946, 66, 302.

22 G. Skript, "American Non-ferrous Foundry Practice," *Foundry Trade Jnl.*, 1946, 78, 319.

23 H. Lepp, "Slags and Fluxes," *Metal Industry*, 1946, 68, 205, 237, 252 and 260.

treatment to give high hardness values comparable with those of beryllium copper. Cook and Alexander²⁴ have reported a full investigation of the heat-treatment and mechanical properties of copper containing from 5-60% of nickel together with from 5-30% of manganese. All were prepared in the form of rolled strip, and some also as drawn rod and wire. By cold-rolling alone the hardness could be increased from roughly 100 V.P.N. to approximately 250 V.P.N., depending on the composition and comprehensive tables are given of hardness determinations after heat-treatment for various times up to 192 hours, at temperatures between 300° and 700° C. Hardness values of well over 400 V.P.N. were of frequent occurrence, the highest recorded figure being 586 V.P.N. Tensile tests on selected materials showed strengths up to 86.7 tons/sq. in. on rod and 110 tons/sq. in. on wire after cold working followed by heat-treatment. Elongations were of the order of 1-4% for these high strengths, but useful combinations of properties, such as 70 tons/sq. in. with 10% elongation and 50 tons/sq. in. with 20% elongation were obtainable by suitable combinations of composition, rolling schedule and heat-treatment. It seems probable that the hardening is due to the "ordering" of the solid solution lattice, and not to precipitation.

Beryllium-Copper.—Beryllium-copper continues to increase in popularity, especially for the springs of delicate instruments. Two papers on the production of beryllium and of beryllium-copper cannot, therefore, fail to be of interest. In the first of these Kjellgren²⁵ describes the production of pure beryllium oxide by fractional crystallisation of the sulphate, and its subsequent reduction to the metal by carbon in an arc furnace. Copper is added to the charge when it is desired to produce a beryllium-copper master alloy. The other paper, by Kawecki²⁶ gives alternative methods, with special reference to the fluoride process for the purification of beryl.

Two valuable papers on the treatment and properties of beryllium-copper alloys have also appeared. The first, by H. G. Williams²⁷ gives the combinations of cold work and heat-treatment to obtain the best all round mechanical properties, and especially to ensure freedom from, or adequate control of "drift" during service in springs calibrated for measuring instruments and similar precision devices. At a temperature of 350° C. the recommended heat-treatment periods for minimum "drift" are 18 minutes for material cold worked to a half-hard condition, or 45 minutes for annealed stock. For maximum tensile strength, however, the somewhat shorter times of 13 minutes and 30 minutes, respectively are advised.

Gohn and Arnold²⁸ have recorded a wide series of investigations of the tensile properties, hardness and fatigue of beryllium-copper strip, with and without additions of nickel or cobalt. The materials were obtained from different sources and the work covered a period of nine years. In this brief note it is impossible adequately to describe their comprehensive studies,

and all users of beryllium-copper are advised to read the original paper. Despite variations in composition, including beryllium content, it was found that all the materials could be heat-treated to meet the test requirements of the current tentative A.S.T.M. specifications (B. 120-41T and B. 194-45T), though the temperature and time of heat-treatment were more critical when the beryllium content was low than when it was high. On the whole fatigue strengths were fairly consistent and ranged from about 14.3 to upwards of 22 tons/sq. in. for 10⁸ reversals of stress, depending more upon the degree of cold rolling prior to the precipitation hardening treatment than upon the composition, or source of manufacture. Polishing the specimen tended to improve the fatigue strength.

A general point from this paper which deserves mention is that, when heat-treated to give the maximum tensile strength, the proximity of the yield point to the ultimate stress combined with low ductility make it difficult to use beryllium-copper springs in applications requiring adjustment after assembly. For such purposes a certain degree of under- or over-ageing is preferable.

Copper-Manganese-Zinc Alloys.—Continuing their comprehensive investigations of the properties of copper-manganese-zinc alloys, Dean and his collaborators²⁹ have reported upon seven alloys containing 60% of copper and from 5-25% of manganese.

The solidus was determined micrographically and was found to range from about 840° to 900° C. Without manganese 60 : 40 brass shows the $\alpha + \beta$ structure, but the progressive addition of manganese diminished the amount of the β phase, and with 20% manganese the alloy consisted entirely of α after annealing for one hour at 650° C. and quenching in water. In the wrought and annealed condition tensile strengths ranged from 25-30 tons/sq. in., with elongations between 38 and 51%. Cold rolling induced strengths up to 47 tons/sq. in. with elongations of about 3%.

These properties are not in themselves particularly striking, and it is unfortunate that important practical attributes such as resistance to corrosion and dezincification, hot-working qualities and machinability were not studied. It may be inferred, however, that the addition of manganese improves the cold-working properties of $\alpha + \beta$ brass, for there appeared to be no difficulty in cold rolling 60 : 40 brass containing 5% of manganese to a reduction in thickness of 80%.

Antimony in Cartridge Brass.—While the decision of the Government to send a considerable tonnage of fired cartridge cases across the Atlantic for refining to some extent diminishes the urgency of the problem, the researches of McLean and Northcott³⁰ on the effect of antimony, derived from antimony fulminate, with and without lead and sulphur on the properties of 70 : 30 brass are opportune. Fifty-five brasses containing varying proportions of these three impurities, separately and together, were prepared and investigated. The solid solubility of antimony in 70 : 30 brass was found to decrease from 0.6% at 550° C. to about 0.01% at 200° C., and the tendency to grain-boundary embrittlement when antimonial brass is held at temperatures between 200° C. and 450° C. is ascribed to this diminished solid solubility. The limiting

²⁴ M. Cook and W. O. Alexander, "The Physical Properties and Temper Hardening Characteristics of Copper-Nickel-Manganese Alloys," *J. Inst. Metals*, 1946, 7, (6), 381.

²⁵ B. R. F. Kjellgren, "The Production of Beryllium Oxide and Beryllium-Copper," *Electrochemical Soc. Preprint No. 89/5*, Apr., 1946.

²⁶ H. C. Kawecki, "The Production of Beryllium Compounds Metals and Alloys," *Electrochemical Soc. Preprint No. 89*, Apr., 1946.

²⁷ H. G. Williams, "Heat-treating Beryllium-Copper for Peak Performance," *Iron Age*, 1945, 156, 58.

²⁸ G. R. Gohn and S. M. Arnold, "The Fatigue Properties of Beryllium-Copper Strip and their Relation to Other Physical Properties," *Amer. Soc. Test. Mat., Preprint No. 56*, June, 1946.

²⁹ R. S. Dean, J. R. Long, T. B. Graham and R. G. Feustel, "Physical Properties of Copper-Manganese Zinc Alloys containing 60% Copper and 5-25% Manganese," *Metals Tech.*, 1946, 14 (1), T.P. 1956.

³⁰ D. McLean and L. Northcott, "Antimonial 70 : 30 Brass," *J. Inst. Metals*, 1946, 72 (2), 555.

antimony content for cold rolling was 0.05%, but higher percentages could be tolerated for hot rolling. Both lead and sulphur impaired the ductility and somewhat intensified the embrittling effect of antimony, while antimony likewise enhanced the injurious effects of these elements. Antimonial embrittlement could be overcome by the addition of either phosphorus or lithium, but the latter element has an adverse effect on the mechanical properties of the brass.

Aluminium Bronzes.—Largely because of their high resistance to oxidation, the aluminium bronzes have long been regarded as pre-eminent among the copper-base alloys for service at moderately elevated temperatures, and it is surprising that so little information has been published regarding their creep and other mechanical properties when heated. A welcome contribution to the subject has been made by Voce³¹ who records tensile tests on thirteen different aluminium bronzes at room temperature, 250° and 400° C. under various conditions of heat-treatment, and creep tests at the same temperatures on three selected materials. In reviewing the published information on the creep of copper-base alloys, none was found with properties superior to those of the aluminium bronzes described in the paper in question. The best alloy investigated was that conforming in composition to BS. 1072/3, and containing 10% aluminium with 5% each of iron and nickel. Whether sand cast or extruded, this material withstood a tensile stress of 13 tons/sq. in. for a creep rate of 10^{-4} strain units per day, and over 5 tons/sq. in. for 10^{-5} per day.

Copper-base Bearing Alloys.—As the result of a systematic investigation of copper-base alloys covering a considerable range of composition, Eash³² has developed a new alloy for bearings. The recommended composition is copper containing 8% nickel, 10% lead, 2% tin and 1% antimony. Compared with a bearing bronze containing 10% tin and 10% lead, the new alloy has superior wearing qualities, equivalent compressive yield stress, but lower ductility. For low-bearing pressures the tin can be omitted. The resulting alloy has very high resistance to wear, but the yield point is about 30% lower than when tin is present. In producing the alloy, overheating in the furnace should be avoided; chill castings gave particularly high resistance to wear.

An entirely different approach to the development of copper-base bearing metals has been made by Hensel, Larson and Swazy³³ who used a sintered powder capable of precipitation hardening by heat-treatment. The material which they investigated was copper containing nickel and silicon in the proportions required to form nickel silicide. After experiments with other compositions the following was adopted: 2.4% nickel, 0.8% silicon, 0.3% phosphorus, balance copper. A master alloy containing approximately ten times these concentrations of nickel, silicon and phosphorus was prepared and powdered, an easy operation because of the extreme brittleness of the material. This was mixed with copper powder in the requisite proportion, pressed at 25-40 tons/sq. in. and sintered in hydrogen or cracked ammonia at 1,000°-1,040° C. for about one hour. Optimum properties were obtained by quenching from 850° C.

31 E. Voce, "The Mechanical Properties Including Creep of Aluminium Bronzes at Elevated Temperatures," *Metallurgia*, 1946, 35 (265), 3.

32 J. T. Eash, "Nickel-Antimony-Lead-Copper Bearing Alloys," *Metals Tech.*, 1946, 12 (8), T.P. 1937.

33 F. B. Hensel, R. I. Larson and E. F. Swazy, "Silicide-hardened Copper Compacts for Bearings," *Metals Tech.*, 1946, 13 (3), T.P. 1976.

and ageing for from four to six hours at 450° C. The average hardness was then about 186 V.P.N., with a tensile strength of from 22-27 tons/sq. in. and elongation up to 2%, the fatigue limit being about 8 tons/sq. in. for upwards of fifty million cycles. Practical bearing tests under conditions intermediate between those of automobile and aircraft connecting rod bearing service gave excellent results.

The copper-lead bearing alloys, whose use was extended during the war, appear to have come to stay. They contain up to 40% of lead, the remainder being mainly copper, and are commonly made in the form of thin shells, with a backing of steel strip. Three essentially different methods are in use for the fabrication of the shells—namely, casting, powder metallurgy and electro-deposition. Until recently the technique of these processes has been to a considerable extent shrouded in secrecy, but within the year a good description of each of them has been published. Lamb and Jeter³⁴ give details of the continuous casting process used by the Ford Motor Company, while at the end of a paper on bearing alloys in general by Ellis³⁵ a full description of the powder metallurgy method has been appended by Barera of the Federal-Mogul Corporation. Electro-deposition is dealt with by Bollenrath.³⁶

Wrought High Tin Bronzes.—The transformation by annealing of cast high tin bronze from a relatively "short" unworkable material into a tough ductile alloy suitable for cold rolling is by no means a new discovery; indeed at least one important British firm has exploited it for many years, but it has never attracted a great deal of attention. An opportune reminder is supplied by Pell-Walpole³⁷ who investigated the densities, mechanical properties and cold-working characteristics of a series of bronzes containing up to 14% of tin. Heat-treatment of the castings to absorb the tin-rich phase did not greatly alter the properties of the bronzes containing up to 10% of tin, but increased both the strength and ductility of those of higher tin content. For instance one sample of the cast 12% tin alloy had an elongation of 80% after soaking at 700° C. for 16 hours. After similar heat-treatment the 14% tin alloy had a tensile strength of 28.5 tons/sq. in. with the surprisingly high elongation of 60%. In the heavily cold-rolled condition, after 80% reduction in thickness, the tensile strength of this material was 64 tons/sq. in. with 2% elongation, a useful combination of properties for springs, while after re-annealing, it had the attractive tensile strength of 35 tons/sq. in. with an elongation of 58%.

An extension of this work by Pell-Walpole, Kondic and Forrester³⁸ covered the addition of up to 8% of aluminium to a similar range of tin bronzes, and showed that the work-hardening and annealing characteristics were in general comparable with those of the binary alloys. Special precautions were necessary during melting and pouring to avoid interdendritic porosity and entrapped oxide films which gave rise to difficulties in hot and cold rolling.

34 T. W. Lamb and E. C. Jeter, "Continuous Casting of Bearing Strip," *Materials and Methods*, 1946, 22 (5), 1567.

35 O. W. Ellis (with L. A. Barera), "New Developments in Bearing Alloys," *Commod. Min. Met. Bull.*, 1946, Sept. (Trans. Vol. 45), 447.

36 F. Bollenrath, "Some Properties of Electrodeposited Copper-Lead Alloys," *Monthly Rev. (Amer. Electroplaters' Soc.)*, 1946, 39 (1), 15 and 38.

37 W. T. Pell-Walpole, "The Effect of Tin Content on the Properties of Degassed Chill-cast Tin Bronze," *J. Inst. Metals*, 1946, 72 (1), 1.

38 W. T. Pell-Walpole, V. Kondic and P. G. Forrester, "The Effects of Aluminium on the Constitution and Working Properties of Tin Bronzes," *J. Inst. Metals*, 1946, 72 (5), 293.

Corrosion and Oxidation

Sea-water Corrosion.—Using the series of wrought high tin and tin-aluminium bronzes prepared by Pell-Walpole, Cuthbertson³⁹ investigated their resistance to impingement, deposit attack and simple immersion corrosion in sea-water, in comparison with cupro-nickel and aluminium brass, in order to determine their suitability for use as condenser tubes. Bronzes containing not less than 10% of tin were superior to cupro-nickel and aluminium brass in impingement attack, and the addition of aluminium tended to improve their resistance to other forms of corrosion. Aeration of the sea-water had a lesser adverse effect on the bronzes than on the standard condenser tube alloys used for comparison, and a simple pre-filming process was developed by means of which the resistance of the bronzes to impingement and general corrosion could be further improved.

Prolonged investigations by the British Non-Ferrous Metals Research Association on the effect of iron on the resistance to corrosion of cupro-nickels in sea-water has led to patents^{40, 41} covering such materials. The full range of composition embraced by the wider of these patents extends from 2-25% of nickel with from 0.5-4% of iron. The addition of iron to the low nickel alloys within this range so improves their resistance to sea-water that they are equal to relatively expensive cupro-nickels of higher nickel content which are frequently used for marine condenser tubes and similar purposes. The alloys can be further improved by heat-treatment both in mechanical properties and, at least to some extent in resistance to corrosion.

Atmospheric Corrosion.—A contribution by Tracy⁴² to the symposium on Atmospheric Exposure Tests on Non-Ferrous Metals sponsored by the American Society for Testing Materials in February, 1946, serves as a timely reminder of the very extensive series of atmospheric corrosion tests conducted by this Society over a period of ten years. The paper summarises the results on two coppers and nine wrought copper-base alloys exposed for periods of 1, 3, 6 and 10 years in nine American localities, four of which were industrial, three marine and two rural. Corrosion was assessed by loss of weight and by diminution of tensile strength. Broadly it can be said that the industrial atmospheres were the most deleterious, considerably more so than the marine atmospheres while, as might be expected, there was relatively little corrosion at the rural sites. Brasses tended to dezincify in the industrial and marine atmospheres, but no seriously penetrative attack was encountered. In this connection, however, it should be noted that the specimens were not under stress during exposure, and had stress been present it is possible that intercrystalline failures, similar to season cracking, might have occurred.

Oxidation at Elevated Temperatures.—A somewhat similar investigation dealing with the oxidation and scaling of a wide range of copper alloys at 400°C. in purified air and in air containing controlled amounts of such impurities as moisture, sulphur dioxide and hydrochloric acid gas has been recorded by Hallows and

Voce.⁴³ Weighed cylinders of 23 different coppers and copper-base alloys were heated in a stream of the required atmosphere for 5 hours, cooled overnight and reweighed after detaching any loose scale, this cycle of operations being repeated until the change of weight per cycle became approximately constant. As a class the aluminium bronzes proved to be far more resistant to oxidation than any other material, though a silicon bronze was but little inferior.

The same authors⁴⁴ carried out an investigation of the alleged attack of superheated steam upon aluminium bronzes, and found that no trouble need be expected provided that the steam remained pure. The presence of active impurities such as sulphur dioxide or chlorine, however, gave rise to penetrative corrosion similar in general character to the well known "dezincification" of brasses.

Physical Metallurgy

Recrystallisation and Grain Growth of Copper and Brass.—By far the most important recent contribution to our knowledge of the physical metallurgy of copper is the latest work of Cook and Richards⁴⁵ on the rate and mechanism of its recrystallization.

Electrolytic copper strip, after various degrees of cold rolling, was annealed for different times at a series of increasing temperatures, the proportion of recrystallised metal being determined metallographically. It was found that the hardness was a linear function of the proportion of recrystallised metal, and that hardness values could therefore be taken as a criterion of the degree of recrystallisation. On this basis an extensive series of tests was carried out to correlate the degree of recrystallisation with time and temperature of annealing, and with the preliminary cold-rolling reduction. Mathematical analysis of the results indicated that softening took place in two stages, referred to as recovery and recrystallisation respectively, each of which was an "activated process" in the thermo-dynamical sense. Recovery precedes recrystallisation and can be regarded as an incubation process during which lattice distortion is removed before activation of the recrystallisation nuclei can occur.

Values for the activation energy under various conditions were determined, as well as the size of the recrystallisation nucleus, which for the annealing temperatures considered varied from about $3.5-5.5 \times 10^{-5}$ cm. When strip is cold rolled with reductions which decrease the mean thickness of the crystals below this value, recrystallisation results in severe "preferred orientation" giving rise to directional properties in the material.

Though the experiments were conducted on copper only, they reflect a method of approach to the fundamental theory of recrystallisation which is of universal applicability.

Of a similar nature, though much less profound, are the researches of Walker⁴⁶ on the recrystallisation of cold rolled cartridge brass. Sheet which had been annealed to give uniform grain size and hardness was cold rolled with reductions of thickness of from 5-70%

39 J. W. Cuthbertson, "The Resistance to Corrosion by Sea-water of some α -Tin and α -Tin-Aluminium Bronzes," *J. Inst. Metals*, 1946, 72 (5), 317.

40 Brit. Non-Ferrous Metals Res. Assn., E. A. G. Liddiard and R. May, "Improved Alloy," *Brit. Pat.* 577,065, May 3rd, 1946.

41 Brit. Non-Ferrous Metals Res. Assn., E. A. G. Liddiard, G. L. Bailey and R. May, "Improved Alloy," *Brit. Pat.* 578,283, June 21st, 1946.

42 A. W. Tracy, "Resistance of Copper Alloys to Atmospheric Corrosion," *Amer. Soc. Test. Mat. Symposium on Atmospheric Exposure Tests on Non-Ferrous Metals*, Feb., 1946.

43 A. P. C. Hallows and E. Voce, "Action of Various Atmospheres on Copper and Copper Alloys at 400°C," *Metallography*, 1946, 1 (200), 95. (NOTE:—The arrangement of the tables relative to the text of this publication causes confusion. Corrected copies are obtainable from the British Non-Ferrous Metals Research Association, Euston Street, London, N.W. 1.)

44 A. P. C. Hallows and E. Voce, "Attack of Superheated Steam on Aluminium Bronze Alloys," *Metallography*, 1946, 1 (201), 119.

45 M. Cook and T. L. Richards, "Observations on the Rate and Mechanism of Recrystallisation in Copper," *J. Inst. Metals*, 1946, 72 (1), 1.

46 H. L. Walker, "Grain Size Produced by Recrystallisation and Consequence in Cold-rolled Cartridge Brass," *Univ. Illinois Eng. Expt. Station Bull. No. 359*, 1946.

and annealed at temperatures between 300° and 700° C., for periods up to 8 hours. Recrystallisation and grain size were assessed micrographically while slip bands, curved twin boundaries and etching characteristics were used as a criterion of the presence or absence of strain. Hardness determinations were also made.

It was concluded that annealing occurred in three stages, namely recovery, recrystallisation and coalescence, or grain growth, in which unstrained grains absorb other unstrained grains due to the difference in surface energy between grains of different sizes. In these conceptions there is nothing new, and they are in line with the conclusions of Cook and Richards on copper, except that the latter work was concerned with the first two stages alone. Walker, however, goes on to deduce an equation indicating that the grain size, after recrystallisation is complete but before grain growth commences, decreases smoothly as the degree of cold rolling is increased. He found no evidence of the formation of abnormally large grains at this stage after critical degrees of cold rolling or times and temperatures of annealing, and suggested that confusion on this point had arisen in the past by failure to differentiate clearly between recrystallisation and grain growth.

Spatial Grain Size.—Discussions of recrystallisation and grain growth raise the question of the determination of grain size. To the experienced metallographist it is a fairly easy matter to determine area or the so called "diameter" ($\sqrt{\text{area}}$) of the average crystal visible in a plane section. The simplest method is to match the specimen at a known magnification with an excellent set of standard photomicrographs originally prepared by the American Society for Testing Materials and now incorporated in B.S./S.T.A. 7 of the British Standards Institution. A paper by Johnson⁴⁷, however, serves as a reminder that crystals are three dimensional and that it is not an easy matter to correlate the observed planar grain size with their real size in three dimensional space. A moment's consideration shows that a conglomeration of crystals, even though their spatial size were identical, would reveal a wide range of planar sizes when examined on a random metallographic section. Only a few of the crystals would be cut in the neighbourhood of their maximum width, while others, cut near their corners, would appear as minute crystallites. There is clearly no simple relationship between the average grain size as normally determined and the spatial grain size, which depends as much upon the range of planar grain sizes encountered in the section under observation as upon their average value.

Statistical considerations are involved and these form the basis of the clear and practical instructions given by Johnson for the computation of the spatial grain size from an ordinary photomicrograph. He claims that, with the help of the diagrams and tables which he gives, the calculation may be completed in ten minutes. For the control of grain size of brass and copper in industry, ordinary planar determinations are probably sufficient, but it is important to consider spatial grain size in fundamental researches such as those of Walker on grain growth in brass just described.

Technical Cohesive Strength and the Creep of Copper and Monel.—McAdam, Geil and Woodard⁴⁸ have

reported creep tests on copper and Monel metal in which the attempt was made to keep the strain rate constant by periodical readjustments of the load. For a number of years McAdam has championed the use of the "technical cohesive strength" of metals as a criterion of the deformation which the material will endure without fracture. In the simplest case the technical cohesive strength may be visualised as the tensile stress which would have to be applied equally to all the faces of a cube of metal to cause rupture. Clearly under such conditions no deformation, other than possibly a small increase of volume, could occur. Such a test would be difficult to carry out in practice, but can be to some extent simulated by using a tensile specimen with a deep, sharp notch to prevent necking. Suppose tensile tests were performed on notched and un-notched specimens of copper rod cold drawn to different degrees, then according to McAdam both the technical cohesive strength, indicated by the notched specimens, and the true stress at which the un-notched specimens yield would increase with the degree of cold work. The yield stress would, however, increase more rapidly than the technical cohesive strength, and at the point at which they become identical, fracture would occur. In this latest paper McAdam and his collaborators apply such considerations to annealed and to cold-worked copper and Monel metal, and give diagrams showing the variation of their true mechanical properties for strain rates ranging from slow creep tests to ultra-rapid tensile tests, over the full range of temperature from near the absolute zero to their respective melting points. Quite apart from its theoretical aspects, the paper gives valuable information on the creep properties of copper, though it is unfortunate that straightforward extension-time curves are omitted. Work of a similar nature has been published by MacGregor and Fisher⁴⁹ though it is only indirectly concerned with copper.

Hardness Testing Procedure.—A notable contribution to the technique of hardness testing has been made by Crow and Hinsley⁵⁰ with special reference to the testing of heavily cold-rolled strip, where directional properties are likely to affect the relative lengths of the diagonals of the diamond impression. The geometry of the indentation was studied in detail and refined methods of measurement and calculation developed. The paper includes a comprehensive table of "corrected" hardness values, and suggests the desirability of introducing certain modifications into British Standard Specifications Nos. 427 and 485.

49 C. W. MacGregor and J. C. Fisher, "Tension Tests at Constant True Strain Rate and Velocity Modified Temperature for the Plastic Flow of Metals," *J. Appl. Mechanics Preprints* (Trans. A.S.M.E. Papers Nos. 45, A2 and A8), Nov., 1946.

50 T. B. Crow and J. F. Hinsley, "Some Anomalies and Some Refinements in the Diamond Pyramid Hardness Testing of Heavily Cold-rolled Strip," *J. Inst. Metals*, 1946, 72 (7), 461.

THE November issue of *Royal Metal Finishing*, a bulletin circulated privately to responsible executives who wish to be kept in touch with the latest developments in metal finishing. This issue deals with bright zinc plating. Information is given regarding the type of solution, current density, temperature, cathode efficiency, anodes, and on fault sand their rectification. Those interested in metal finishing should make an effort to secure this and subsequent bulletins as published from the Technical Development Department, International Corrodeless, Ltd., Lockfield Avenue, Enfield, Middlesex.

47 W. A. Johnson, "Estimation of Spatial Grain Size," *Metal Progress*, 1946, 49, 87 and 1192-B.

48 D. J. McAdam, C. W. Geil and D. H. Woodard, "Influence of Strain Rate and Temperature on the Mechanical Properties of Monel Metal and Copper," *Amer. Soc. Test. Mat.*, 1946, 46, Preprint No. 54.

Magnesium and its Alloys

A Survey of Recent Technical Progress

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Although the total consumption of magnesium has diminished considerably since the end of the war, its alloys are again being applied to their old peace-time uses and new uses are being rapidly developed. In some fields, the new jet engines for instance, they are contributing materially to efficiency. These peace-time developments are due largely to recent technical progress, a comprehensive survey of which is given in this article. The author deals with progress in extraction and production, fabricating processes, engineering processes, protection, research on alloys, structure, corrosion, design and applications.

Extraction and Production

AS has been the case with other strategic materials the production of magnesium alloys has been curtailed as a result of the ending of the war. (A very large proportion of the United Kingdom's manufacturing capacity is at present in "cold storage" and the enormous plants which were built in the U.S.A. are also, for the most part, closed down or held in a state of readiness. These drastic cuts in production were, of course, inevitable, occasioned by the existence of greatly expanded production capacity as compared with pre-war levels and by the dislocation which is bound to occur during the transition from war to peace production. Comprehensive figures for to-day's production of magnesium are not available in this country, but it is estimated that the present U.S. production is of the order of 7,000 tons per annum. This compares very favourably with pre-war U.S. production which was of the order of 3,000 tons annually. The American demand has, in fact, risen during recent months to such an extent that the Dow Chemical Company has announced that it is reopening its Velasco plant. The production of magnesium is, by agreement of the Quadrupartite Council, prohibited in Germany. Small amounts of magnesium are probably being produced in France and an unknown quantity in Russia.

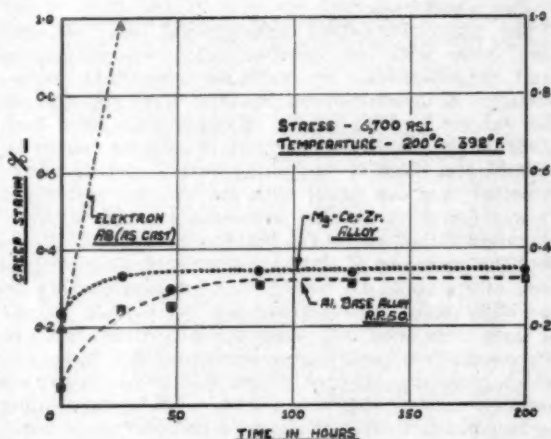
Outside the U.S.A. and the U.K., probably the most important producer is The Dominion Magnesium Corporation of Canada, which continues* to produce the metal by a modified Pigeon process. From the extractational point of view it will be seen from the above brief sketch that the great preponderance of metal being made to-day is produced by the electrolytic process (either M.E.L. or Dow).

Development work by M.E.L. now permits the production of metal from the electrolytic cell of considerably higher purity than was possible previously.

Of the metal which is produced in this country by far the larger proportion is still devoted to conversion into castings and only about 15% is converted into sheet, tubes, rod, etc.

Fabrication Process Development

Casting.—Several lines of development have been proceeding in this field, of which probably three are of outstanding importance. The first is that there is a considerably increased interest in the use of pressure-casting processes as applied to magnesium alloys and, in fact, a new company has been floated (Messrs. Stone-



	Mg-Ce-Zr ALLOY	AL BASE ALLOY	Elektron A8
CREEP RATE AFTER 120 HRS. 10 ⁻⁵ INCHES/INCH/HOUR	0	0	3500
CREEP STRAIN AFTER 120 HRS. PER CENT	0.32	0.31	—

Fig. 1.—Comparative creep characteristics of Mg-Ce-Zr alloys with Elektron A8 and aluminium-base alloy R.R.50.

After Murphy and Payne²⁷

Elektron A8 :—(8% Al, 0.5% Zn, 0.3% Mn)

0.8-2% Cu, 0.8-1.75% Ni

R.R.50 { 0.05-0.2% Mg, 0.25-1.4% Fe

{ 0.75-2.8% Si, 0.05-0.3% Ti }

Fry) which takes considerable interest in magnesium pressure die casting. In the peace-time market the emphasis is naturally very much on the question of cheapness and magnesium alloy pressure die castings can play a very important part in this direction.¹ A problem which has always been of considerable difficulty in the successful pressure die casting of magnesium alloys is the question of the avoidance of flux inclusions. This problem is now being effectively solved in different ways and excellent castings of first-class finish and durability are being produced.

The second development is also concerned with the production of castings of low cost. This has to do with the evolution of suitable foundry methods for making reliable castings in a commercial quality magnesium alloy. Such an alloy will of course have a wider composition range than is permitted by D.T.D. specifications and also have somewhat higher impurity limits.

* It is, however, reported that this plant is not now (November, 1946), producing.

¹ "Magnesium Die Castings." Powell and Scott, *Product Engineering*, Oct., 1945.

The aluminium content naturally plays an important part in the foundry response of a magnesium base alloy, and the problem of making, with a given technique, uniformly good castings from a material which necessarily varies in composition by 1-2% aluminium is not easy, but is being solved very effectively by close attention to foundry detail. With commercial grade material, very low-priced magnesium alloy sand castings are now being made.

As far as aircraft quality material is concerned, an advance has been made by the introduction of new D.T.D. specifications for cast materials, which regulate the compositions much more closely than was permitted by earlier specifications; furthermore, the new D.T.D. specifications call for mechanical tests on the ingot material, thus providing a quality safeguard for both producer and caster.

The third important development in the cast field deals with the question of grain refinement (and degasification) by methods other than superheating. A number of publications have appeared on this subject.^{2, 3, 4, 5, 6, 7, 8, 9} Examinations have been made on the mechanism of grain refinement caused by superheating, and it was found that a specific microstructure was associated with superheated material.¹⁰ It was found by parallel development work at Basic Magnesium Inc. and at the Battelle Memorial Institute that the grain size of aluminium-containing magnesium base alloys could be refined without superheating by the addition of carbon-containing compounds. Many of these were tried but preference was finally given to compounds free from oxygen, nitrogen or hydrogen, and which contained chlorine which, if evolved, might act usefully as a de-gasifying agent. The grain-refining agency which at present seems to be optimum is hexachlorethane. This when added in amounts of about 0.1% refines the grain (giving typical superheated structures) and reduces any tendencies to gas porosity which might otherwise appear. This grain-refining process is now being introduced in the U.K., although cautiously, in order to give its effects a very close examination. Tests have already been made on the corrosion resistance of magnesium-aluminium-zinc alloys refined by carbon additions, and it has been found that alloys treated in this way have a corrosion performance not materially different from that of alloys grain-refined by superheating. It is of interest to note that very difficult analytical examination is needed to detect the presence of carbon in magnesium alloys; however, a successful technique is described in a recent publication¹¹ which shows that in carbon grain-refined alloys the carbon content is vanishingly small.

The process of grain refinement by addition of some suitable compound, thus avoiding the need for super-

heating, was introduced by the Germans during the war.¹² The compound they used was termed "Elfinal" and consisted of anhydrous ferric chloride. The Germans claimed that the mechanical properties of the standard alloys were slightly improved and that the scatter in properties was distinctly reduced. The process was, however, dangerous, since ferric chloride is very difficult to maintain in an anhydrous condition. There is some evidence that the Germans were themselves doing some experiments on carbon grain refinement of magnesium-aluminium alloys as early as 1942.

It is to be expected that the mechanical properties of the ordinary aluminium-containing casting alloys may be made more uniform by the introduction of hexachlorethane.

Rolling.—In the range of the newly evolved magnesium-zinc-zirconium alloys there are some remarkable developments in workability as affecting rolling processes. These are such that, as has been reported by Major Ball,¹³ the alloy can be rolled into bar or section from cast stock on the same mills and with the same high speeds and heavy pinches as for steel. This method of production should prove to be very cheap and has two other main advantages. It leads to the absence of, or to very greatly reduced, directionality of properties in the products, and very long lengths can be made. Rolling can, therefore, be used instead of extrusion when the section forms allow and the quantities required justify the provision of the necessary rolls. Minimum properties at present proposed for rolled bar and section in the zirconium-containing alloys are given in Table I. It has also been found that it is possible to effect very heavy reductions when the rolling conditions are correct, on the known alloy composition ranges as well, and the application of "steel mill technique" for most magnesium-base alloys appears to be only a question of time and availability of plant.

TABLE I.—D.T.D. SPECIFICATION MINIMUM FOR MAGNESIUM-BASE ALLOY ROLLED BAR AND SECTION.

	0.1% P.S. (t.s.l.)	U.T.S. (t.s.l.)	E% on 2 in.
ZZ Draft D.T.D. 622	14	30	12
ZC Draft D.T.D. 613	8	15	14

ZZ alloy contains 0.7% zirconium and approximately 3% zinc.
ZC alloy contains 0.7% zirconium and approximately 4% cadmium.

Forging.—Little published information is available in connection with developments in forging, although attention is directed to a paper on this question by Rustay and Rote.¹⁴ It is to be noted that the new magnesium-zinc-zirconium alloys again show very outstanding workability by good forging performance and the alloys can be drop-stamped into complex forms. This is in strong contrast to the standard method of forging of magnesium alloys which, with few exceptions, must be hydraulically worked. The high permissible working temperature of 500°C. also makes possible very heavy deformation in a single heat. The minimum properties at present proposed for high-strength forging alloys containing zirconium are given in Table II.

It is of interest to note that the Germans were operating at Bitterfeld a 30,000-ton hydraulic press for light alloy forging. One of the reasons which led them to use

9 "Grain size in light and ultra-light aluminium-magnesium alloys." Bastien, *Chim. et Ind.*, 1941, no. 27.

8 "A study in factors influencing grain size in Magnesium alloys and a carbon inoculation method for grain refinement." Mahoney, Tarr and Le Grand, *A.I.M.M.E.*, 1945, 12, T.P., 1892.

4 "Grain refinement of a carbothermic magnesium alloy by superheating." Hultgren, Mitchell and York, *A.I.M.M.E.*, 1945, 12, T.P., 1853.

5 "Grain refinement of magnesium alloys without superheating." Hultgren and Mitchell, *A.I.M.M.E.*, 1945, 12, T.P., 1854.

6 "Recent developments in magnesium foundry melts." Eastwood, Davis and DeHaven, *Light Metal Age*, Feb., 1946.

7 "Importance and factors determining the grain size of Magnesium castings." Eastwood and Davis, *Aluminium and Magnesium*, March, 1946.

8 "Superheating of Magnesium alloys." Tiner, *A.I.M.M.E.*, 1945, 12, T.P., 1935.

9 "Grain refinement of Magnesium casting alloys." Davis, Eastwood and DeHaven, *American Foundryman*, VIII (1), 1946.

10 "An exploration of the problem of superheating in magnesium-base alloys." Fox and Lardner, *J. Inst. Met.*, 1945, 41 (1).

11 "Determination of Hydrogen, Carbon and Nitrogen in magnesium alloys." Bobalek and Shrader, *Ind. and Eng. Chem. (Anal. Ed.)*, 1945, 17 (9).

12 "Production and Fabrication of Magnesium Alloys." I.G. Farbenindustrie, Bitterfeld and Aken. C.I.O.S. report, Item 21, File No. XXIX-3.

13 Lecture delivered by Major G. J. P. Ball to the first International Congress of the Magnesium Association in New York, Oct., 1946.

14 "Design of Magnesium Forgings." Rustay and Rote, *Product Engineering*, Oct., 1945.

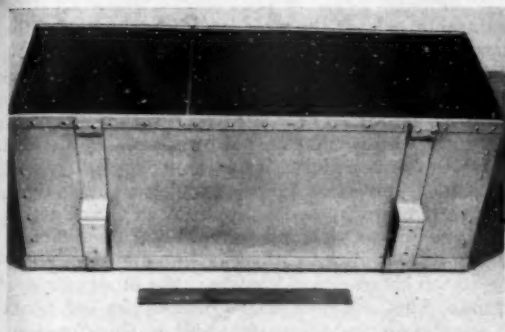


Fig. 2.



Fig. 4.

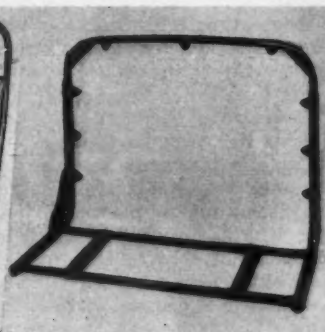


Fig. 6.

Fig. 2.—Doffin box. Textiles.—Riveted construction in Elektron sheet and extruded material. Weight, 9 lb. 8 oz. Fig. 4.—Aircraft seat in Elektron.—Seat made by two welders previously inexperienced in Elektron, after one week of tuition in welding Elektron alloys. Weight of seat in Elektron, 10 lb. 4 oz. Overall length, 40 in. Overall height, 40 in. Overall width, 22 in. Material principally in $\frac{1}{4}$ in. dia. \times 14 s.w.g. tubing in Elektron AZM (D.T.D. 348). Fig. 6.—Bus seat frame.—Welded Elektron tubular construction with welded-in parts in Elektron sheet material. Weight, 4 lb. 3 oz.

TABLE II.—D.T.D. OR EQUIVALENT SPECIFICATION MINIMUM FOR MAGNESIUM-BASE FORGING ALLOYS.

	0.1% P.S. (t.s.l.)	U.T.S. (t.s.l.)	E% on 2 in.
1. ZZ (hydraulic press)	13	19	8
Draft D.T.D. 619.			
2. ZZ (impact)	11	17	8
Draft D.T.D. 729.			
3. D.T.D. 880 (e.g., AZM)	10	18	8
(Hydraulic press).			
4. A.S.T.M. B91-44T Alloy AZ. 81 (e.g., Dow J.)	9.8 (0.2%)	17	6
(Hydraulic press).			
5. A.S.T.M. B91-44T Alloy AZ. 80 (e.g., Dow O)	10.7 (0.2%)	18.8	5
(Hydraulic press).			
6. A.S.T.M. B91-44T Alloy AT. 35 (e.g., A.M.C. A.M.65)	8.9 (0.2%)	15.6	6
(impact).			

such an enormous press was the necessity as they saw it of hydraulic forging for magnesium alloys. With this press they were able to make extremely large aircraft forgings up to 11 metres long.

Extrusion.—No published information is available concerning advances in the extrusion of magnesium. However, again, the magnesium-zinc-zirconium alloys are outstanding in their extrudabilities. They can be extruded over a wide temperature range and at very high speeds—e.g., up to 100 ft. per minute. Difficult sections can be extruded without cracking at speeds near 40 ft.

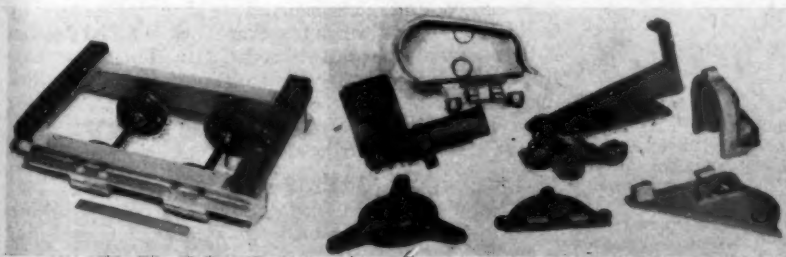


Fig. 3.

Fig. 3.—Piano truck.—Construction in Elektron sections with steel axles, rubber wheels and pads. Total weight, 36½ lb. Weight of Elektron parts, 13½ lb. cast parts for cigarette-making machinery in Elektron.

per minute. The best mechanical properties are achieved at lower speeds and temperatures, the resultant bar and section having an exceedingly fine grain—less than 0.003 mms. The mechanical properties of extruded

TABLE III.—HIGH-STRENGTH MAGNESIUM-BASE ALLOY EXTRUSIONS.

D.T.D. OR EQUIVALENT SPECIFICATION MINIMA.			
	0.1% P.S. (t.s.l.)	U.T.S. (t.s.l.)	E% on 2 in.
ZZ (high tensile). Draft D.T.D. 733 (up to and including 3 in. dia. or minor sectional dimension) . .	17	23	8
D.T.D. 259 (e.g., AZM) (up to and including 3 in. dia. or minor sec- tional dimension)	11	17	10
A.S.T.M. B.107-44T Alloy No. AZ. 80 (e.g., Dow O). (Round and squares up to 1½ in.)	12.5 (0.2%)	19.2	9
OTHER PROPERTIES (TYPICAL).			
	Compressive 0.1% P.S. (t.s.l.)	Fatigue limit (50 cycles \times 10 ⁶) (t.s.l.)	
ZZ (high tensile) (1-1 in. round bar) . .	14	9.5	
D.T.D. 259 (e.g., ZM)	10	8.5	
A.S.T.M. .107-44T Alloy No. AZ. 80 . .	9.8	8.6 (500	
(e.g., Dow O)	(0.2%)	\times 10 ⁶)	

The Izod value of extruded ZZ is 5-6 ft. lbs.

zirconium-containing and other magnesium-base alloys are given in Table III.

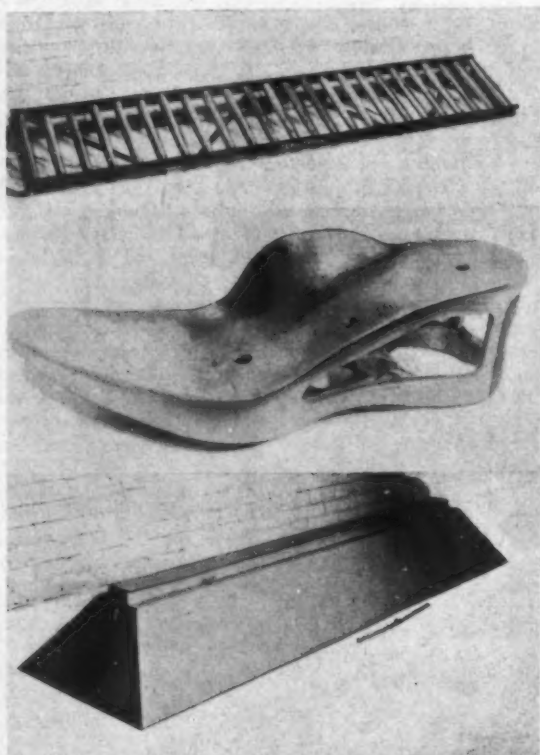
Engineering Process Development

Welding.—During the past eighteen months there has been much activity in the continued application of the shielded arc process to the welding of magnesium alloys. Messrs. The British Oxygen Company have developed a welding torch for the Argonarc process which is now commercially available and which operates very effectively on either D.C. or A.C. An electronic high-frequency circuit is also employed which has the effect of assisting arc stabilisation. Progress in the Argonarc development was reviewed at a recent Symposium on light alloy welding held by the British Welding Research Association and a valuable paper¹⁵ on the Argonarc welding of magnesium alloys by Doré, Percival and Sillifant was presented

¹⁵ British Welding Research Association, Symposium on the welding of light alloys, London, Oct., 1946. Papers to be published shortly, and available from the Association.

to the meeting. This, and other work, has shown that the Argonarc welding of magnesium alloys is now in a more healthy state than previously, and that welds of excellent quality can be produced by both manual and automatic methods. Weld efficiencies in strong sheet alloys of as high as 95% can be attained.

Experimental work has also been proceeding in the Laboratories of the British Non-Ferrous Metals Research Association on the reasons for local strength scatter in long lengths of welded sheet conforming to D.T.D. Specification 118. The results of this work by Pendleton¹⁵ were also presented to the British Welding Research Association Symposium. Pendleton's work showed that the local strength scatter is due mainly to two causes, firstly, to local grain growth in the parent sheet due to irregularities in heat input (e.g., as caused by tacking and by stopping and restarting a weld) and also to the adverse effects in testing of malalignment across the weld.



Top—Fig. 7.—Portable gravity roller conveyor in Elektron. Construction in Elektron materials. Length, 10 ft. Weight, 70½ lb.

Centre—Fig. 8.—Cast Elektron block for surgical boot. Made using a cork block for a pattern and lightened by improvised coring and drilling. Weight, 13 oz.

Bottom—Fig. 9.—Billiard table lamp shade. Riveted Elektron sheet material. Weight, 13 lb.

A further development in the welding field has been the issue by the British Welding Research Association of their pamphlet T. 16 entitled: "Technique for the gas welding of magnesium alloys." While this does not describe anything which is inherently new, the compilation of this booklet is of considerable utility to the industry.

Work which is parallel in objective to that which is attained by the Argonarc technique is going on in another direction; this is the development of gas-welding fluxes

for magnesium alloys, the residues from which shall be non-corrosive. Some success has been achieved in this direction by the development of all-fluoride flux mixtures, but a good deal of work remains to be done to improve the fluxing characteristics of the mixtures. Attention has also been attracted by some work done in Germany by Mäder and Laves¹⁶ on the evolution of strong magnesium-base alloys with better weldability. These investigators worked on an alloy of the Elektron AM537 type (magnesium containing 1.5% manganese plus about 0.4% rare earth metals) and endeavoured to reduce its weld cracking tendency by other alloying additions. They claimed that the addition of about 1.5% aluminium was of great benefit in this direction. Finally, Tylecote¹⁷ has published a very useful review of the available literature on the spot-welding of magnesium alloys.

Fig. 10.—Billiard table accessories in Elektron. The snooker triangle is a sand casting and the cue rests die castings.

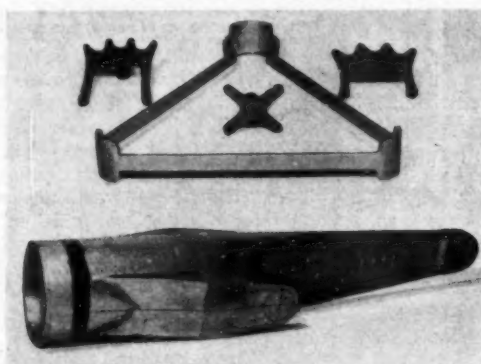


Fig. 11.—Sand-cast aircraft control column in Elektron. Length, 22½ in.

Sheet working.—Although it is known that the working of magnesium alloy sheet has reached a high pitch of perfection in this country and that excellent work is being done, particularly in complex fuel tank construction, little information on sheet working has been made generally available in this country in the recent past. A review of published information (available at August, 1945) dealing with the manipulation of magnesium alloy sheet and extrusions has been published by Goddard.¹⁸ This brings together much detailed data on hot pressing and forming of sheet. In addition, a paper by Gulliksen¹⁹ describes the deep drawing of thick magnesium sheet, the thicknesses involved changing from ½ in. down to ¼ in. This work was mainly in connection with propeller domes.

Protection

Little of outstanding importance has been published recently on this subject, although a paper by Oldt²⁰ gives a general review and Mason²¹ describes a method of producing heavy protective coatings on magnesium

16 "Weld cracks in magnesium-manganese-cerium alloys." Mäder and Laves, *Aluminium*, 1943, 23 (4). Translation in *Magnesium Review and Abstracts*, 1946, VI (1).

17 "The spot welding of magnesium. (A review of available literature)." Tylecote, *Welding*, 1946, 14 (3).

18 "The Manipulation of magnesium alloy sheet and extrusions." Goddard, August, 1945, F. A. Hughes and Co. Ltd., Abbey House, Baker Street, London, N.W. 1.

19 "Stamping and deep drawing magnesium." Gulliksen, *Product Engineering*, Oct., 1945.

20 "Protective and decorative treatments of magnesium." Oldt, *Light Metal Age*, 1946, 4 (3).

21 "A protective finish for magnesium alloys." Mason, *Iron Age*, 1946, March 21.

alloys by electro-chemical treatment. An excellent general review²² on the protection of magnesium alloys appeared in *Metals and Alloys* (now *Materials and Methods*) early in 1945. A revised D.T.D. Specification²³ on the protection of magnesium rich alloys against corrosion was issued in April this year. This gives a much fuller account of the methods to be followed than did the earlier specification.

Research Development

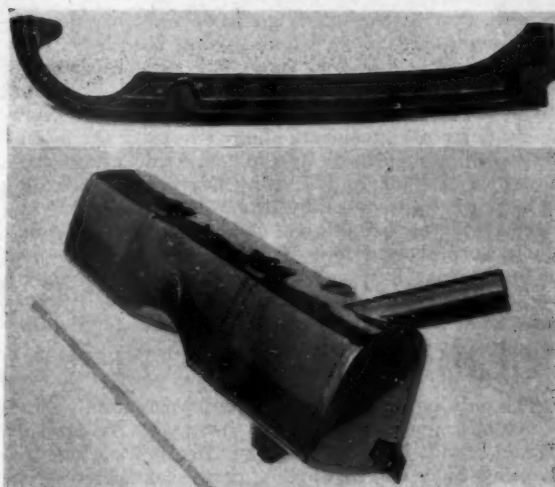
Properties of alloys.—Developments in this category come under two headings.

(a) **Development work on known alloys.**—A considerable amount of work has been done in the investigation of microporosity,^{24, 25} gas content,²⁶ mechanical properties^{27, 28, 29, 30, 31, 32, 33, 34} and heat-treatment^{35, 36} of the standard magnesium-aluminium-zinc alloys. Baker's paper²⁴ on microporosity has done a great deal to clarify the mechanism of this phenomenon and should prove to be of value to those foundrymen who are new to the idiosyncrasies of magnesium alloys. Many of Baker's findings are, in fact, applicable to other light alloys besides those of magnesium. It has generally been considered that gas is not a particularly important consideration in the technology of magnesium alloy casting. However, recent American work lays rather more emphasis on this question, and the use of hexachlorethane in its function as de-gasifier (as well as grain refiner) does seem to have some beneficial effect.

The two surveys^{27, 28} on the mechanical properties of the magnesium-aluminium-zinc systems produced results which were in close agreement with each other and which indicated, in general, that high zinc concentrations were to be avoided. This also is in line with Baker's work which indicated that zinc was likely to increase the tendency to microporosity. The tendency in U.S. alloy compositions away from the use of higher zinc contents has been continuing in the recent past and compositions on the other side of the Atlantic are now approaching more nearly those standard in Europe. The interest in the mechanical properties



Fig. 12.—Sand-cast portable air drill housing in Elektron. Length, 10 in. Height, 6 1/2 in.



Top—Fig. 13.—Sand-cast bus bonnet support in Elektron. Length, 23 1/2 in.

Bottom—Fig. 14.—Road vehicle petrol tank. Welded Elektron sheet construction with welded-in cast Elektron flanges. Weight, 6 lb. 11 oz.

of the standard alloys at temperatures other than atmospheric is evidenced by the work of Moore and MacDonald²⁴ by McAdam, Mebs and Geil.³⁰ The mechanical properties of magnesium alloys at low temperatures are seen to be satisfactory and no evidence of the existence of brittle ranges has appeared.

(b) **Development work on new alloys.**—The properties of the magnesium-zinc-zirconium alloys, particularly in cast form, have continued to be the subject of very close examination, and properties which constitute a considerable advance on the existing alloys are now being obtained. As cited recently by Major Ball,³³ the high-strength alloy considered most suitable for cast purposes is one containing 4.5% zinc and 0.6–0.7% zirconium. The alloy gives its best properties after a simple low temperature heat-treatment for 24 hours at 180°C. In this state the following mechanical properties are to be expected:—

0.1% P.S.	U.T.S.	% elongation on 2 in.
t.s.i.	t.s.i.	
10	17	8

A further casting alloy containing 3% rare earth metals and 0.7% zirconium has been developed for high-temperature applications.³⁷ The average room-temperature tensile properties of this alloy in the form of D.T.D. type test bars are as follows:—

0.1% P.S.	U.T.S.	% elongation on 2 in.
t.s.i.	t.s.i.	
6.5	11	7

The chief virtue of this alloy lies in its resistance to creep at temperatures up to 200°C. Fig. 1 shows the comparative creep curves under a load of 3 tons at 200°C. for the alloys Elektron AS, the magnesium-cerium-zirconium alloy, and the well-known aluminium base alloy RR50.

Apart from the magnesium-zinc-zirconium alloys and the magnesium-rare-earth-metal-zirconium alloys, it

²² Materials and Methods Manual No. 3. *Metals and Alloys*, 1945, Feb.

²³ D.T.D. Specification No. 911A. Issued by H.M. Stationery Office.

²⁴ "Microporosity in magnesium alloy castings." Baker, *J. Inst. Met.*, 1945, 71 (1).

²⁵ "Microporosity in magnesium alloy castings." Eastwood and Davis, A.F.A. Fiftieth Annual Meeting, Cleveland, May, 1946.

²⁶ "The effect of Gas on the properties of Magnesium." Busk and Marande, *American Foundryman*, May, 1945.

²⁷ "Some properties of sand-cast alloys in the magnesium-rich corner of the magnesium-aluminium-zinc system." Busk and Marande, A.I.M.M.E., 1946, 13 (4). T.P. 2009.

²⁸ "The properties of some magnesium-aluminium-zinc casting alloys and the incidence of microporosity." Fox, *J. Inst. Met.*, 1945, 71 (8).

²⁹ "Properties and characteristics of common magnesium casting alloys." Hanawalt, Nelson and Busk, *American Foundryman*, Oct., 1945.

³⁰ "The technical cohesive strength of some steels and light alloys at low temperatures." McAdam, Mebs and Geil, A.S.T.M., 1944, preprint No. 27.

³¹ "The notch sensitivity in static and impact loading of some magnesium-base and aluminium-base alloys." Doan and McDonald, A.S.T.M., 1946, preprint No. 18.

³² "The fatigue strength of some magnesium-sheet alloys." Jackson and Grover, A.S.T.M., 1946, preprint No. 37.

³³ "The fatigue strength of lap joints in some magnesium sheet alloys." Grover and Jackson, A.S.T.M., 1946, preprint No. 28.

³⁴ "Tensile and creep strengths of some magnesium-base alloys at elevated temperatures." Moore and McDonald, A.S.T.M., 1946, preprint No. 55a.

³⁵ "Rates of high temperature oxidation of magnesium and magnesium alloys." Leontis and Rhines, A.I.M.M.E., 1946, 1, (4). T.P. 2003.

³⁶ "Heat-treatment of magnesium alloys." Burks, Thomson and Jominy, *The Foundry*, 1945, 73 (4).

³⁷ "Magnesium-Cerium-Zirconium Alloys: Properties at Elevated Temperatures," Murphy & Payne, *J. Inst. Metals*, 1946, 74 (3).

appears that little work is going on on other possible magnesium-base alloys. Leontis and Murphy³⁸ have recently published some work on the properties of cerium-containing magnesium alloys at room and elevated temperatures. The alloys investigated, however, are mainly those in the known range of the magnesium-cerium-manganese alloys, and including those described by Mäder and Laves.¹⁸ One possible new alloy series has been described by Hume-Rothery, Raynor and Butchers,³⁹ this being in the magnesium-lithium range. Their work showed that if 26-30% atomic per cent of high purity lithium is added to magnesium then a body centred cubic structure is produced which they considered might offer the possibility of a ductile alloy considerably lighter than magnesium itself.

Structure

The only important publication on magnesium alloys which has appeared recently is that by R. Heidenreich, Gerould and McNulty.⁴⁰ This deals with electron metallography and its application to magnesium alloys. This work is of interest in that the authors were able to relate a fine structure appearing in some magnesium-aluminium alloys, and which had hitherto been undetected, to the corrosion behaviour. This fine structure was found to be a dispersion of an iron-aluminium phase.

Corrosion

There is sustained interest in the corrosion resistance of magnesium-base alloys, particularly those which are of higher purity. Fox and Bushrod⁴¹ found that the solution-treated magnesium-aluminium-zinc alloys corroded much faster in the solution-treated condition than in other states. They found also that the presence of manganese could to a large extent offset the adverse corrosion effects of relatively high iron concentrations. In later work⁴² these investigators found that the corrosion performance of laboratory specimens was very greatly influenced by the state of the surface and the method of surface preparation. When the samples were of high purity the condition of surface preparation was of far greater significance than for the materials of normal purity. When specimens were very carefully prepared with pumice powder the lower iron content materials behaved considerably better under conditions of immersion testing than did specimens of higher iron content. Fox, Bushrod and Mayer⁴³ examined the problem of the production of low iron content alloys by manganese settlement processes and evolved a technique for making alloys of an iron content of 0.005% or less on a large scale. They also examined the problem of the prevention of re-contamination by iron when melting high-purity ingot in ferrous crucibles and it appears from their work that an alloy steel rich in manganese is probably the most suitable ferrous material to use for melting pots.

The avoidance of superheating is an important factor in the question of re-contamination by iron in the case of high-purity ingot and in this connection the use of hexachlorethane as a grain refiner is naturally impor-

tant. A useful publication by Peloubet⁴⁴ dealt with the sea/air corrosion of magnesium alloys and showed that under conditions of marine atmospheric exposure, ordinary magnesium-base alloys are comparable in performance to many aluminium alloys. Two other papers of interest on the corrosion of magnesium are those by Eastwood, Finck and Davies⁴⁵ and by Coates.⁴⁶

Much attention has recently been devoted to the problem of the protection of steel pipelines by means of sacrificial anodes of magnesium and this technique is now being tried out experimentally in many parts of the world. A useful general paper on anodic protection of this kind has been written by Mudd.⁴⁷ The question of the stress corrosion of magnesium alloys has received considerably more attention in the U.S.A. than in this country for the reason that the sheet alloy so far used here almost exclusively (Elektron AM503) has no stress corrosion problems. The alloy containing 6% of aluminium and 1% zinc has, however, been found in sheet form to be somewhat prone to stress corrosion, particularly under heavy stresses. For this reason the Americans are tending to use less of this alloy in sheet form and to pay more attention to an alloy containing 3% aluminium and 1% zinc. In this country development work has been proceeding on a sheet alloy containing 4-5% aluminium with a very low zinc content. This alloy has been found to be readily rollable, to give good mechanical properties and, with low iron and low nickel contents, to give outstanding corrosion performance.

Much development work on the question of improved paint finishes for magnesium alloys has also been proceeding and considerably improved finishes are available from certain paint manufacturers. Tests indicate that these new schemes give a corrosion and weathering performance on painted specimens of the order of ten times better than that of previously standard protected material. The new magnesium-zinc-zirconium alloys have been tested for corrosion behaviour and have been found to give good results both in the cast and in the wrought forms, being equal in performance to the magnesium-manganese alloys.

Design

Considerable interest has been shown in those properties of magnesium alloy structures which are closely connected with design efficiencies. In this connection the work of Rappleyea⁴⁸ and Eastman, McDonald and Moore⁴⁹ may be mentioned. Fisher^{50, 51} has also done work of this kind, and he directs attention to the decisive influence which elongation may have in structures which are exposed to conditions of specific strain. Walker⁵² has also examined the effect of the rate of loading on the ultimate tensile strength and elongation of magnesium alloys. He found that most magnesium-base alloys were insensitive to variations in the rate of tensile testing but that the alloys Elektron AM503 and Elektron AM537 in sheet form were sensitive to a considerable

38 "Properties of cerium-containing magnesium alloys at room and elevated temperatures." Leontis and Murphy, A.I.M.E., 1946, 13 (3), T.P., 1995.

39 "Equilibrium relations and some properties of magnesium-lithium and magnesium-silver-lithium alloys." Hume-Rothery, Raynor and Butchers, J. Inst. Met., 1945, 7 (12).

40 "Electron metallographic methods and some results for magnesium alloys." Heidenreich, Gerould and McNulty, A.I.M.E., 1946, 13 (3), T.P. 1979.

41 "Further observations on the protective influence of manganese in the corrosion of aluminium-containing magnesium alloys." Fox and Bushrod, J. Inst. Met., 1946, 14 (5).

42 "The influence of some different surface preparations on the corrosion of magnesium-base alloys of low and normal iron content." Fox and Bushrod, J. Inst. Met., 1946, 14 (1).

43 "Some factors in the reduction of the iron content of magnesium-base alloys." Fox, Bushrod and Mayer, J. Inst. Met., 1946, 73 (3).

44 "Sea-air corrosion of magnesium alloys." Peloubet, Metals and Alloys, 1945, 21 (5).

45 "The relative corrosion resistance of magnesium alloys in salt water." Eastwood, Finck and Davis, Light Metal Age, 1946, 4 (4).

46 "The acid corrosion of magnesium." Coates, J. Inst. Met., 1945, 71 (9).

47 "The control of pipe-line corrosion—a manual." Mudd, Corrosion, 1945, 1 (4), and 1946, 11 (1).

48 "Strength of magnesium-alloy columns." Rappleyea, J. Aero. Sciences, 1945, July.

49 "The relation of stress to strain in magnesium-base alloys." Eastman, McDonald and Moore, J. Aero. Sciences, 1945, July.

50 "A discussion on the notch impact test and its interpretations." Fisher, Metallurgia, 1945, 40, Sept. and Oct.

51 "The importance of ultimate extension as an engineering property of materials." Fisher, Metallurgia, 1946, 44, Ju. e.

52 "An examination of the effect of rate of loading on the ultimate tensile strength and elongation of magnesium alloys." Walker, Metallurgia, 1945, 33, Oct.

extent, the U.T.S. figures rising with increasing loading speeds. He suggests that actual speeds of testing should be quoted when test results are being published.

Applications

The total consumption of magnesium in aircraft is naturally considerably diminished under peace-time conditions: the well-tried wartime applications, however, continue as before: the landing wheels for the York aircraft, for example, made in magnesium alloy

weigh only about 280 lb. Magnesium alloys are finding their way into the new jet engines, to the efficiency of which they contribute materially. Magnesium alloys are also finding their way back into their old peace-time markets in the automobile, electrical, textile, machine tool and optical equipment fields. Magnesium alloy cycle rims and griddles and frying pans are very recent innovations which are of distinct technical interest. Figures 2-14 illustrate present-day examples of the application of magnesium alloys in peace-time industry.

The Colorimetric Estimation of Antimony in Aluminium Alloys Using Potassium Iodide and Thiourea

By J. H. Bartram and P. J. C. Kent

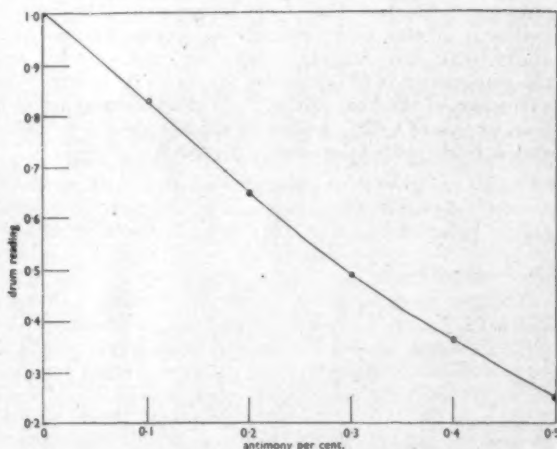
A colorimetric method for the estimation of antimony in aluminium alloys is described. Results show very good agreement with the volumetric and polarographic methods; reproducibility of results is also shown to be of a high order. The method is also applicable to brass and bronzes using a slightly different opening technique details of which are given.

THE antimony content of aluminium alloys is usually determined volumetrically by means of the method developed by the British Aluminium Co.¹ This method in the hands of an experienced operator gives accurate and consistent results. A fair amount of practice is needed, however, and in the hands of inexperienced operators the results obtained are decidedly erratic. A rather simpler method was, therefore, sought which could be carried out in much less time and by relatively inexperienced operators.

Antimony tri-iodide in dilute solution has a very intense yellow colour and can be used to detect very small quantities of antimony. As little as 0.01% antimony is visible to the eye as the tri-iodide and rather less is detected by the Spekker absorptiometer. The tri-iodide can be produced very simply from any antimony salts in solution by the addition of potassium iodide. In the presence of excess potassium iodide antimonious salts are first reduced to the antimonious state with the liberation of iodine. Antimonious salts react directly with potassium iodide to give antimonious iodide SbI_3 . The colour of the SbI_3 solution is almost directly proportional to the antimony content of the solution over a limited range. If the antimony iodide colour, therefore, can be produced without interference from other metals, a simple colorimetric method for the estimation of antimony is available.

By the use of thiourea, copper can be kept in solution as a colourless soluble complex and all iodine which may be liberated is reduced to colourless HI. It is the separation of the copper and antimony sulphides which makes the volumetric method so tedious, and the elimination of this separation is a particular advantage of the colorimetric method.

The only other element likely to be present in aluminium alloys which will also produce a yellow colour under these conditions is bismuth, and this occurs so very rarely that it need not in general be considered. If it does occur, however, in any quantity greater than 0.03%, the method is inaccurate, and it is necessary to



carry out the antimony estimation volumetrically. Up to 0.03% bismuth the antimony figure obtained by the method described below can be taken as representing bismuth + antimony. The bismuth can then be estimated separately², and the correct antimony figure obtained by subtraction.

The time required for one estimation is 30 minutes.

Description of Method

Reagents Required.

- 40% Sodium hydroxide solution (40 gms. in 100 ml. water).
- 50/50 Nitric acid (by volume).
- 50/50 Sulphuric acid (by volume).
- 50% Potassium iodide solution (50 gms. in 100 ml. water).
- Solid Thiourea.
- Solid Hydrazine sulphate.

Weigh out a 400 mgm. sample of the alloy into a 150 ml. tall beaker and add 10 ml. of 40% sodium

¹ "Analysis of Aluminium and its Alloys"—British Aluminium Co. Ltd., 1941.

² Bartram and Kent—*Light Metals*, May, 1946, p. 229.

hydroxide solution. When the initial effervescence has subsided warm gently to complete the reaction and dilute slightly. Add 15 ml. 50/50 sulphuric acid and 10 ml. 50/50 nitric acid. Boil until all solids have dissolved then remove from the hot plate and cool about one minute. Add $\frac{1}{2}$ gm. of solid hydrazine sulphate to reduce all the iron present to the ferrous state, replace on the hot plate and boil for a further two minutes. Cool to room temperature and when cold add 2-3 gms. solid thiourea, followed by 40 ml. of 50% potassium iodide solution. Transfer the contents of the beaker to a 200 ml. sugar flask. Make up to the mark with distilled water, mix well, filter through a Whatman No. 3 filter paper into a dry flask and measure on the Spekter as soon as possible after sufficient filtrate is available for measurement. Use Ilford spectrum violet No. 601. filters and 1.0 water to water setting with the filament lamp. The lapse of time between filtration and measurement should not exceed 15 minutes under any circumstances, otherwise there is the possibility of colloidal sulphur being produced by decomposition of the thiourea.

The range of antimony content which can be covered by this method is from 0.0-0.5% using a 400 mgm. sample, giving a range in drum readings of from 1.0-0.25. The standard graph is a very slight curve over this range. (Fig. 1). Above this range, however, it flattens out very suddenly. Also a very large excess of potassium iodide is required to produce the coloration, so that above 0.5% antimony it is not only very wasteful, but the concentration of potassium iodide tends to effect the extinction of the final solution. If the antimony content is in excess of 0.5%, a smaller sample should be taken and a fresh calibration curve prepared.

TABLE I.

Alloy	% Sb	Lab. A.	Lab. B.	Lab. B.
		% Sb	% Sb	% Sb
		Colorimetric Method	B.A. Co. Method	Polarographic Method
89157 B.A. 35	0.365	0.39	0.38	0.39
89840 "	0.385	0.39	0.40	0.41
89432 "	0.30	0.29	0.35	0.32
89422 "	0.37	0.37	0.40	0.36
90108 "	0.445	0.53	0.47	0.45
90105 "	0.43	0.46	0.44	0.40
89433 "	0.41	0.44	0.44	0.40
Sb Std.	0.295	—	0.30	0.31
Sb Std.	0.105	—	0.103	0.093

TABLE II.—DETERMINATIONS CARRIED OUT BY DIFFERENT OPERATORS ON DIFFERENT DAYS.

B.A. 35 89432	B.A. 35 90108	B.A. 35 (Standard Alloy)
% Sb	% Sb	% Sb
0.30	0.435	0.29
0.295	0.445	0.29
0.295	0.435	0.29
0.31	0.455	0.295
0.295	0.435	0.29
0.30	0.435	0.29
0.30	0.435	0.30
—	—	0.30

Three different operators, determinations spread over four days, not more than two determinations per alloy per day.

Exact weights of hydrazine sulphate and thiourea are not necessary. They can be added very conveniently from small nickel scoops.

The solutions for the standard graph are prepared by adding given quantities of an antimony solution of known strength to solutions of an antimony-free alloy, processed as above, just before boiling with hydrazine. The standard antimony solution was made up from 99.9%

pure antimony powder passed through a 150-mesh sieve, and magnetised to remove any possible traces of metallic iron. It was taken into solution as follows:—

Into a 1-litre tall beaker 0.4 gm. was weighed out and heated for a short time with 250 ml. of concentrated hydrochloric acid saturated with bromine. Most of the antimony went into solution, and the few small grains remaining were taken up by adding 25 ml. of liquid bromine, when the remaining antimony at once went into solution with a flash of light. The use of bromine is necessary to prevent the loss of any antimony as stibine, and during the heating, as the bromine colour disappears from the hydrochloric acid, more bromine must be added continuously to keep a deep yellow tint in the solution. When the last traces of antimony were dissolved the solution was boiled to expel the excess bromine, cooled and made up to 1 litre with distilled water. Using a 400 mgm. sample, 1 ml. of this solution is equivalent to 0.1% antimony.

Large samples were taken from a number of B.A. 35 type alloys containing 0.3-0.5% antimony. After each individual sample had been carefully mixed it was divided into three portions. One portion was retained by ourselves for colorimetric estimations, the other two were sent to independent laboratories for colorimetric and polarographic estimations. Results are shown in Table I, and it will be seen that the colorimetric figures are in very good agreement with those obtained by the other two methods. In Table II is shown the reproducibility of the results obtained on three of the samples when the estimations were carried out by different operators on different days. It is very difficult to get such close agreement using the volumetric method.

The method is also applicable to brasses and bronzes if the opening technique is varied as follows:—

Dissolve the sample of brass or bronze as far as possible by attacking with the 50/50 sulphuric acid only and then add the 50/50 nitric acid dropwise. Boil for a few more minutes then cool the solution and add the 40% sodium hydroxide solution. If the nitric acid is used first the antimony is rendered insoluble. If tin is present there will be a precipitate of stannic oxide, but this can be ignored throughout the rest of the procedure and filtered off after colouring up. We obtained a sample of the British Chemical Standard "Bronze A." This is listed as containing 0.26% antimony. The accompanying certificate shows that 10 different analysts of repute had obtained results on this standard varying from 0.20-0.31% antimony. This seemed to indicate that the available antimony methods were not too reliable, and the details given of the methods used showed that the large number of precipitations involved gave ample opportunity for some loss of antimony. It seems probable, therefore, that the highest figures are most likely to be correct. Using the modified opening technique we were able to estimate the antimony content of this bronze quite successfully, obtaining an average figure of 0.316%. The variation between the 10 estimations amounted to no more than 0.025%. It seems likely, therefore, that this is a reasonably accurate figure.

We should like to acknowledge our indebtedness to Mr. G. H. Osborn and Mr. D. F. Phillips for their assistance in carrying out volumetric and polarographic checks. Our thanks are also due to the Directors of International Alloys, Ltd., in whose Slough Laboratories this work was carried out, for permission to publish this paper.

The Year's Progress in the Production and Application of Alloy Cast Irons

By A. E. McRae Smith, M.A., B.Sc.

Keighley Laboratories Ltd.

Progress in the alloy cast iron field is reviewed. The year has been one of consolidation of the results of past experience, particularly experience gained during the war years when many foundries obtained first class melting plant and sound technical advice. The wider use of ladle additions has resulted in some progress in the production of alloy cast irons of varying composition and physical properties from a single base mixture.

Introduction

THE year 1946 has not been in any way remarkable or outstanding in the production of new types of alloy cast iron, nor in the use of novel alloying elements or combinations thereof. On the contrary there has been a general tendency towards the consolidation and establishment of existing types with some increase and expansion in the applicational field. This widening of the number and types of applications and uses of already established types of alloy cast iron, has been largely associated with the change over from war time to peace-time production in the engineering and allied industries and a consequent reversion to peace time activities by iron foundries normally producing special types of alloy cast iron.

Although various controls are still in operation, most alloys used for the production of special cast irons have been readily available during 1946, and foundries have not experienced any of the difficulties which either restricted the production of certain types of alloy cast irons or else diverted their use along certain channels solely connected with the production of armaments or as castings forming an essential part of plant and equipment used for the making of armaments.

The foundry industry in this country has reaped much benefit from some of its war-time activities, and this is more particularly the case where alloy cast iron is concerned. Quite a large number of foundries were not only able to acquire specialised melting plant, but they were also able to obtain first-class technical advice under conditions which allowed them to gain very valuable experience.

In the same way they were also able to carry out trials which under ordinary peace-time trading conditions they might not have been able to arrange.

It is generally recognised that alloy iron castings, as such, do not find many applications as direct munitions of war, but as components of war-time plant and equipment they are very important. One interesting example of this is the wide use of nickel-chromium-molybdenum cast irons for tools used in the various hot forging processes involved in the production of artillery and other projectiles. The experience gained in this field has already proved of considerable benefit for dies and tools for the production of peace-time articles.

Any brief notes on the progress achieved in the alloy cast iron field during any short period, such as a single year can only deal with a few of the most outstanding features, and show in which way the general tendencies

are being directed, which types have been improved and their uses extended, and which types are being superseded by better and new ones.

Probably the best way to do this is to give a brief survey of the present state of that section of the foundry industry actively engaged in the production of alloy cast irons.

Progress in Production Methods

Production methods have altered little since the years immediately prior to the war, except that more and more use is being made of electric furnace melted metal. Methods of making alloy additions have also remained largely unchanged, but there has been a marked increase in the use, as ladle additions, of exothermic ferro-alloys, particularly exothermic ferro-chromium, such as Chrom X. Ferro-silicon of the same type such as Sil-X, although not strictly an alloying addition material has also become popular with foundries as a convenient method of adding silicon to a low silicon base mixture.

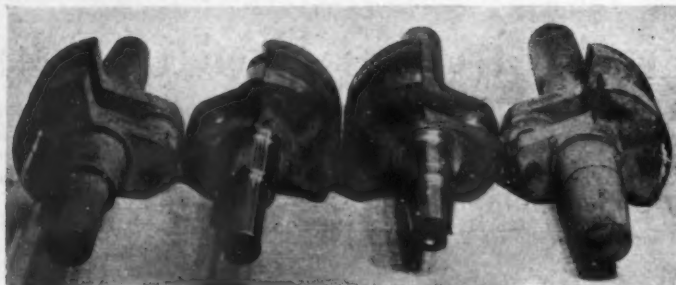
By the wider application of ladle additions the year 1946 has seen some progress in the production of alloy cast irons of varying composition and physical properties from one single base mixture, of low or medium silicon content, the exact range and composition depending on the variety of compositions required and the types of castings being produced.

In certain of the smaller foundries, where the cupola is the only melting unit available, the single base mixture plus ladle addition method is much more reliable than attempting to isolate small quantities of different mixtures during the same cupola melt.

To take a typical example, a base mixture of the following compositional range might be melted in the cupola in bulk.

Total Carbon	3.0 to 3.3%
(or higher carbon ranges as required)	
Silicon	0.9 to 1.1%
(or higher silicon ranges as required)	
Sulphur	0.12% max.
Phosphorus	0.25% max.
Manganese	0.60 to 0.80%

This mixture, in the molten state, could be treated in one cwt., 10 cwt., one ton, or larger lots with such a wide range and quantity of alloying elements so as to provide castings from white or mottled abrasion resisting types, probably with chromium additions, to high strength grey pearlitic molybdenum or nickel-molybdenum cast irons suitable for casting into even quite thin sections and with properties equal to B.S.S. 786, Grade 3 or 4.



By courtesy of Douglas (Kingswood), Ltd., Bristol.

Fig. 1.—Crankshaft castings for petrol engine trucks in high strength acicular nickel-molybdenum cast iron.



By courtesy of Douglas (Kingswood), Ltd., Bristol.

Fig. 2.—Small camshafts made in acicular nickel-molybdenum cast iron. The cams are flame-hardened.

Once the base composition has been settled, it has been found quite easy to maintain it with regularity, and treat either small or large quantities with ladle additions of alloys and/or silicon additions and so obtain final compositions which are much more regular than is possible by charging a variety of mixtures in the cupola.

This scheme has been introduced with success in foundries where a variety of types of alloy cast irons are required and where a bath type of melting unit such as an electric furnace is not available.

Types of Alloy Cast Irons

The more important types of alloy cast irons at present being produced in quantity may be classified as follows:

1. PEARLITIC CAST IRONS:

(a) *Moderate Strength Types.* Small additions of nickel, copper, and chromium are still popular with some foundries. These are used chiefly to control the structure of pearlitic cast irons of moderate strength, improve machinability (e.g. nickel and copper additions) or conversely (chromium additions) to increase hardness and resistance to abrasion. There is a tendency, however, for these alloy additions to be superseded by silicon treated or so called inoculated non-alloy cast irons.

(b) *High Strength Types.* Where the best possible founding properties are desirable in high strength cast irons to meet the requirements of B.S.S. 786, Grade 3 and 4, the medium carbon (3.0 to 3.3% carbon) cast irons mainly of the nickel-molybdenum type both in this country and in the U.S.A. are now tending to supersede really low carbon types of cast iron. In this connection it is interesting to note that Ni-Tensyl iron, once probably the most popular type of the original processed high strength pearlitic cast irons, has been largely replaced by cast iron of the nickel-molybdenum type, also processed by silicon additions, but produced from cupola, rotary furnace, or electric furnace metal with a general total carbon level probably at least two to three points higher than in the original Ni-Tensyl iron type and consequently possessing much better founding properties.

2. ACICULAR NICKEL-MOLYBDENUM CAST IRONS:

During the present year much prominence has been given to the production and application of this type of cast iron. As a true cast iron with improved mechanical properties it possesses the highest strength and toughness, particularly in medium and heavy section castings, in the "as-cast" condition, of any cast iron in commercial production. Here again these properties can be produced at reasonable carbon levels, usually in the region of 2.9 to 3.1% and hence its founding properties are good

and certainly much superior to high strength cast irons of lower carbon content. The process which is covered in this country by British Patent No. 545,102, held by the Mond Nickel Co. Ltd., depends on correlating the composition of the melt, the casting temperature, and the cooling rate so that a cast iron is produced with a matrix consisting of needles of ferrite in an austenitic matrix. This type of structure possesses properties quite different from the more orthodox pearlitic matrix and apart from higher strength in heavy and medium sections, its resistance to shock, as measured by single blow impact tests is particularly high. The alloying elements are nickel usually varying from 1 to 4.5% according to the mass of the casting, and molybdenum ranging from 0.7 to 1.2%.

This type of cast iron is finding a wide field of application and in particular its use for crankshafts for compressors and petrol and diesel engines is growing rapidly.

It is also being used for many other highly stressed engineering castings where high strength and reasonable toughness is required in a readily castable material, where cast iron is used for its rigidity, high damping capacity, good machinability, good wearing properties, and the like, and where a non-ductile material is acceptable.



By courtesy of Douglas (Kingswood), Ltd., Bristol.

Fig. 3.—Castings for wheel hubs for petrol-driven trucks made in acicular nickel-molybdenum cast iron.

It is a very useful material for dies, permanent moulds, and similar applications where wear resistance and high strength are important.

Figs. 1, 2, and 3 show typical examples of the use of acicular cast iron for castings used for petrol driven trucks. Similar crankshafts up to quite large sizes have been produced extensively in this type of cast iron during 1946.

3. WEAR AND ABRASION RESISTING ALLOY CAST IRONS :

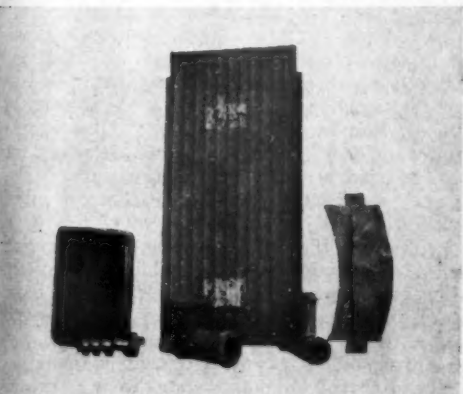
For castings for a wide variety of industries, resistance to abrasion becomes increasingly important since service conditions become more exacting every year.

Although white, chilled, and mottled plain cast irons, as well as chromium containing cast irons (0.5 to 3% Cr.) are still used for ordinary service and where it is only possible to use the cheapest material, the martensitic white and chilled cast irons of the Ni-Hard type have found a wider field of application during 1946 than ever before. In particular the clay working, refractory, and allied industries are becoming fully aware of the benefits to be derived from this type of alloy cast iron. During the year Ni-Hard has become increasingly popular for components of foundry and similar equipment, such as airless shot blast (wheelabrator) blades, shot blast nozzles, cups, and liners for sand slingers, liners, and similar components for the manufacture of concrete pipes, cement-sand tiles, and a host of other components subjected to severe abrasion.

Some investigators have been paying more attention to small additions of boron, tellurium, and similar carbide formers as substitutes for or improvements on chromium as the whitening agent in the production of martensitic or pearlitic white irons, but in Great Britain little commercial progress has been made so far. This statement, of course, does not refer to the use of tellurium as a carbide former in other types of white cast iron such as white iron for the malleable industry.

4. CORROSION OF HEAT-RESISTING CAST IRONS :

These two applications for cast iron are grouped together because any progress made during the year under review has been made in the high alloy types, most of which can be used according to individual composition for both their corrosion resisting qualities and as intermediate heat-resisting materials.



By courtesy of The Sheppridge Stokes Centrifugal Castings Co. Ltd.

Fig. 4.—Group of high-alloy iron castings. The three at the back consist of a casehardening box, electric furnace hearth plate and boiler furnace arch plate, all in 30% chromium cast iron. Those in front are components of meat mincers made in copper-free austenitic cast iron.

The chief progress has really been made in the application of these cast irons and not in the use of new alloys. As in the past the main types used are as follows :

(a) 30-33% Chromium Cast Iron. This material is mainly used for its heat-resisting and low sealing prop-

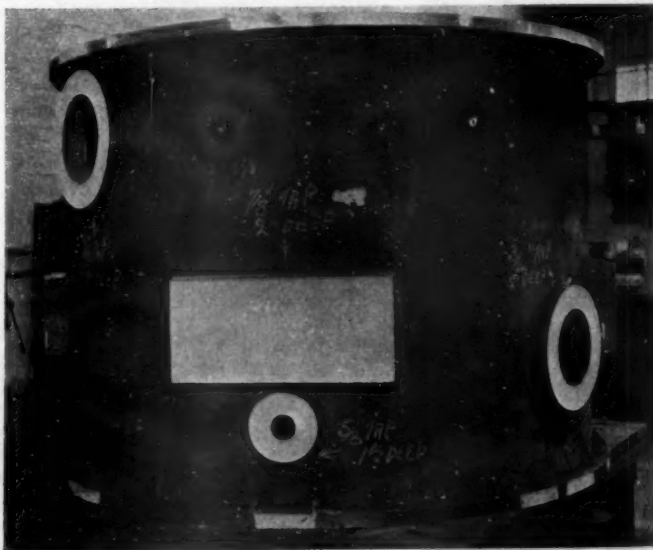
erties. It is also used to a limited extent as a corrosion resisting cast iron.)

The year 1946 has seen considerable progress with this type of cast iron and more foundries have undertaken its production. It is making a much wider appeal to users of special cast irons than previously, but the potential output is still rather limited, due to lack of suitable melting facilities except in a small number of specialised foundries.

(b) *Ni-Resist and Similar Austenitic Cast Irons.* The austenitic cast irons continue to be used for their excellent corrosion resisting properties and their field of application has again been extended during 1946. The chief feature has been the greater availability of really large castings in the Ni-Resist type of austenitic cast iron. Fig. 5 shows a typical large Ni-Resist casting produced during 1946. Castings such as this can be produced to close compositional limits by foundries who specialise in large castings and who have the necessary experience in melting Ni-Resist austenitic cast iron.

Fig. 4 shows a general group of high alloy castings typical of everyday production during 1946. The copper free type of austenitic cast iron is recommended where the castings are to be used as components of equipment for handling edible products and the like.

(c) *NoMag Non-Magnetic Type of Cast Iron.* This continues to be used for suitable applications but there is a tendency, due to changes in design and the use of fabricated materials, light alloys, etc., for its field of usefulness to become restricted rather than to become extended.



By courtesy of Widnes Foundry and Engineering Co. Ltd.

Fig. 5.—Ni-resist calandria casing, 6 ft. 3 in. inside diameter by 4 ft. 10½ in. deep. Weight as cast, 5 tons.

5. SPECIAL TYPES OF ALLOY CAST IRONS :

Among the other types of alloy cast iron the production and application of which has progressed during the year, there is little to report, except in the case of the higher carbon nickel-molybdenum and nickel-chromium-molybdenum types used for their resistance to thermal shock and freedom from "heat checking" or "map lining."

Perhaps this has been more noteworthy in the U.S.A. than in this country. In particular automobile engineers in America have been paying a great deal of attention to improving the service life of the brake mechanism on automobiles and especially on heavy commercial vehicles. Engineers have long recognised the necessity for improving the life of brake drums.

Cast iron has been proved to be the best brake drum material, because it possesses a good coefficient of friction, good wear resistance, good resistance to scoring and good resistance to heat checking. In order to increase the strength of brake drum cast irons, alloy additions have long been used, but it has been recognised for some time that the higher carbon cast irons, that is to say, those containing much graphite have better resistance to heat checking, than cast irons with less graphite. On the other hand higher carbon cast irons possess lower strength and inferior wear resistance.

Additions of molybdenum usually in conjunction with nickel and chromium have been used in the higher carbon irons to counter balance the lower strength.

Typical compositions for heavy duty brake drums being used successfully would be generally as follows:

(a) Chromium-Molybdenum Cast Irons (heavy section drums):			
Total Carbon	3.60 to 3.80%	
Silicon	1.60 to 1.80%	
Sulphur	0.12% max.	
Phosphorus	0.20% max.	
Manganese	0.70 to 0.90%	
Chromium	0.40 to 0.60%	
Molybdenum	0.70 to 1.00%	
(b) Nickel-Chromium-Molybdenum Cast Iron:			
Total Carbon	3.7 ± 0.10%	
Silicon	1.30% upwards	
(according to sectional thickness)			
Sulphur	0.12% max.	
Phosphorus	0.20% max.	
Manganese	0.7 to 1.0%	
Nickel	2.0 ± 0.10%	
Chromium	0.45 ± 0.05%	
Molybdenum	0.50 ± 0.10%	

A Rotary Hearth Furnace

IN the production of tube, rolled strip and sheet, and extrusions in many complex copper alloys it is necessary to exercise very close control of the temperature in heat-treatment operations. In the production of high tin content bronzes, for instance, Earle Bourne & Co. Ltd., who have recently installed a hydraulic extrusion press, have installed an electric furnace to obtain the close range of temperature control necessary for these alloys. It is a rotary hearth furnace, designed and built by The General Electric Co. Ltd., which embodies a number of features incorporated to simplify operation and to eliminate the danger of incorrect heat-treatment of the charge.

The furnace is rated at 175 kW, and gives an output of approximately 2,000 lb. of alloy billets per hour at a predetermined temperature of between 800° and 900° C. Each billet is extruded into tubes immediately it reaches the required temperature. The heating chamber has a cross section 1 ft. 4 in. wide by 1 ft. 6 in. high, the hearth being annular and having a mean diameter of 5 ft. 9 in.

To ensure a minimum heating cycle, and at the same time keeping the surface temperature of the billets within safe limits, the elements are arranged in three zones, each having individual thermostatic control. The final zone is concentrated round the outlet door—

These types of cast iron are also being used for centrifugally or statically-cast drums where a pressed steel insert or liner is "cast in" to form part of the brake drum.

During 1946 similar types of cast iron have been used in this country for other applications where a combination of reasonable strength at elevated temperatures is required, coupled with the maximum resistance to thermal shock and "heat checking." An interesting example relates to moulds, shapes, and similar castings for the glass industry.

6. FLAME HARDENING FOR ALLOY CAST IRONS:

During 1946 much attention and effort has been directed to improving the technique of flame hardening alloy cast irons. Surface hardened cast irons are becoming of increasing importance in the machine tool and allied industries. As is well known, the body of the casting is kept cool while the surfaces to be treated are heated rapidly locally to a temperature which will give a hard surface (450 to 500 V.P.N.) on quenching by water. This rather drastic treatment results in some degree of distortion, which in long lathe beds and similar castings may lead to difficulties.

Compositions are now being used in some cases, where it is possible to obtain the desired hardness by air quenching after the normal local heating, thus greatly reducing the degree of distortion. In most cases this objective is achieved by using suitably controlled compositions containing 2.0 to 3.0% nickel, the actual amount depending on the mass or self-quenching capacity of the casting being treated.

In conclusion, the above notes give a brief review of the major activities in the alloy cast iron field during 1946. It is again stressed that the period has been one of consolidation of the results of past experience and experience gained during the war years, rather than the launching of any new processes and spectacular new types of alloy cast iron.

there are two doors—to ensure that the billets are maintained at the optimum temperature until the last second before being discharged for extrusion.

An Osram photo-electric cell which is fitted to operate through an aperture in the outlet door gives visible warning by means of a lamp when billets are ready for unloading. The beam is directed across the hearth of the furnace at such a height that even the shortest billet will interrupt it. This "electric eye" also acts as a safety device, for once the beam is cut the motor driving the hearth is stopped. If a number of billets are ready for unloading at the same time the broken beam from the photo-cell prevents the hearth from beginning to rotate again until the last billet has been removed.

As the size of the billets may vary, or their composition be such that a different temperature or heating cycle is called for, the hearth drive is worked through a P.I.V. gear and the furnace can thus cater for a diversity of heat-treatments and types of charge.

Ease of operation at the critical stage of transferring a billet from the furnace to the press is essential. To facilitate this process each door is pneumatically raised by means of a pedal, so leaving the operator's hands free to tong the billets into the press as quickly as possible. The two doors are quite independent of each other and cannot be left open unless the operator is working the pedals.

Progress in the Tin Consuming Industries

By John Ireland, M.C., B.Sc.

Director, Tin Research Institute

The scarcity of tin, caused by Japan's invasion of the Eastern tinfields has, during recent years, shut out the possibility of any new or extended employment of tin in industry. In consequence, progress has been of two kinds only; (1) Measures which have enabled industries to conserve their use of tin; (2) the tentative exploration of certain new uses which laboratory investigations suggest may have important commercial application when tin is once more freely available.

IN this review, which is limited to the past two years, tinsplate exemplifies progress directed to tin conservation, while the newer uses are exemplified by the application of tin to steel as a pre-treatment for paint, electro-deposited tin-zinc alloys as a new protective coating for steel, and flux de-gassing in bronze manufacture as the avenue to a range of high-quality alloys with greatly improved mechanical and corrosion-resistant properties.

Tinsplate Developments

In the tinsplate industry the composition of the steel base is now such as to improve materially the resistance of the finished tinsplate to corrosion by many foodstuffs. This has arisen through the wider use of cold-reduced material instead of the hot-reduced steel previously employed. In America the production of hot-rolled sheet has been entirely eliminated; in England about half of the sheet is still hot-reduced, but plans for increasing the cold-rolled material are well under way.

The progress of electrolytic tinning has been more chequered.^{1, 2, 3, 4} No tinsplate of this type is as yet being manufactured in England, but a large plant is in course of erection. In America, however, many large plants are in operation and almost one-third of all tinsplate is electrolytic. These plants appear to be suitable for producing coatings of about 8-12 oz. per basis box as compared with the 20-24 oz. commonly used on normal hot-dipped tinsplate. The new thin coatings are good enough for many dry packs, but they have not yet been improved sufficiently to be adopted for processed foodstuffs, and the balance of evidence suggests that this is not likely to be achieved under normal competitive conditions of supply. The chief advantage of electrolytic tinning is that it saves tin and, hence, provides a cheaper packaging material. The difference in cost between 8 oz. per basis box electro-tin and normal hot-dipped tinsplate carrying 20 oz. is of the order of 7% which must also cover the difference in the costs of applying the tin. Electro-tinsplate can be improved either by increasing the amount of the tin coating, covering the tinsplate with lacquer, or increasing the tinsplate's inherent resistance by a chemical filming operation. The first alternative is not applicable when tin-saving is the objective. The second has a measure of success where lacquering on one side only of the tinsplate is sufficient; where both sides have to be lacquered the product is more costly than normal tinsplate. The third alternative is still under investigation. A simple chromic acid dip is already in common use in the U.S.A. It

would appear that the "Protecta-tin" process developed by the Tin Research Institute, based on phosphates and dichromates of sodium, may give better service. The process is already in use in England and is being increasingly adopted to improve the shelf life of normal tinsplate packages. The extent to which such treatments may broaden the market for electro-tinsplate is not yet determinable.

An interesting suggestion that the eventual trend may lead to thicker rather than thinner tin coatings, at least for the wide group of acid fruits and fruit juices, arises in recent work of the Fruit and Vegetable Preservation Research Station at Camden.⁵ An experiment with Pershore plums established that the life of the pack could be increased from 50-100% by increasing the thickness of the tin coating from 24 oz. per basis box to 40 oz. p.b.b. An increase in shelf life of this order would make enormous difference to the export markets for British fruit.

A wide extension of the market for electro-tinned steel is foreshadowed by recent work by Hedges and Jordan.⁶ Experiments extending over some years, have established that a thin coating of tin on steel is the best pre-treatment prior to painting yet devised. Steel so treated has been painted with a variety of typical paints used in industry, and the panels have been submitted to several types of accelerated weathering along with panels similarly prepared, but using a phosphate pre-treatment, and others without any pre-treatment. The resistance to destruction of the paint is greatly increased and the life of the steel is multiplied several times by this relatively inexpensive treatment.

This effect, though novel, is not surprising when it is recollected that tin has a high inherent resistance to corrosion and a strong affinity for oils. The peculiar ability of tin to retain an oil film is, for example, an important factor in its use for bearings. Printing in colour on tinsplate has long been an art that rivals the best that can be done on paper. Tinsplate is frequently coated with lacquers for packaging certain foodstuffs, and lacquered tinsplate can afterwards be fabricated into containers without spoiling the bond between the tin and the lacquer. It is obvious, therefore, that a thin coating of tin on steel will improve the adhesion of the paints and thus increase the useful life of the product. There is, however, evidence that a thin coating of tin improves corrosion resistance independently of its favourable effect on adhesion.

The paints used included linseed oil and synthetic paints, cellulose, and air and stove drying enamels. The

¹ Brighton, *Iron and Steel Engineer*, 1945. 22.

² Brighton, "Food in Cans," 1944. 4.

³ Lueck and Brighton, *Ind. Eng. Chem.*, 1944. 36.

⁴ Lueck and Brighton, "Can. Food Packer," 1944. 15.

⁵ Annual Report for 1945, Fruit and Vegetable Preservation Research Station, Camden.

⁶ E. S. Hedges and L. A. Jordan, "The use of a Tin undercoat to improve the Corrosion Resistance of Painted Steel." *Jour. Iron and Steel Inst.*, 1945, No. 2.

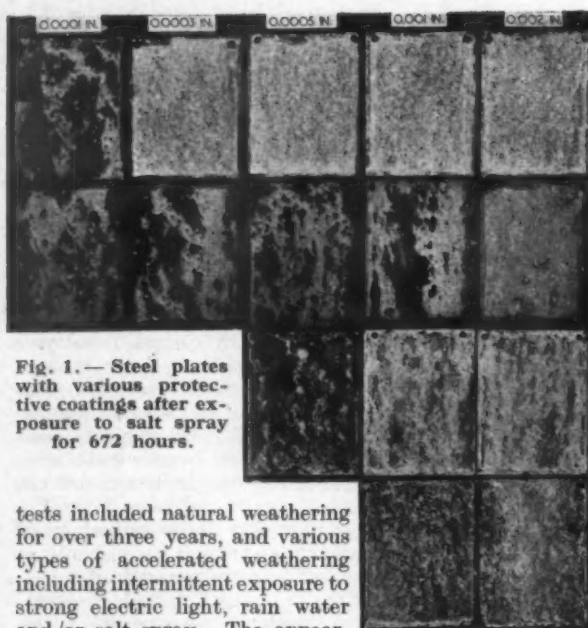


Fig. 1.— Steel plates with various protective coatings after exposure to salt spray for 672 hours.

tests included natural weathering for over three years, and various types of accelerated weathering including intermittent exposure to strong electric light, rain water and/or salt spray. The appearance of the specimens after these tests, varied greatly, depending on the nature and severity of the exposure and on the quantity and quality of the paint used, but the relative performance of the different pre-treatments agreed closely throughout. In each case, where paint had been applied direct to steel, the corrosion had been severe. The specimens phosphated before painting were much better and had held paint well, but rust spots had developed. Those specimens which had been tinned before painting were outstandingly good. The paints adhered firmly and no rust had formed.

The exceedingly small amount of tin required to effect these results may be illustrated by the fact that if an automobile body were coated both inside and outside with tin, the metal cost would be under two shillings, but the sheet metal of the body and mudguards would last several times as long without damage to the paint by corrosion.

It is impossible to say how widely this process may be adopted eventually, nor just how greatly the life of steel equipment can be extended,⁷ until the industrial trials now in hand reach some conclusion. But this joint investigation by the Tin Research Institute, and the Paint Research Station, has shown that tinning is outstandingly the best pre-treatment yet devised for painted steel, and that by this means its useful life may be greatly lengthened.

A further outcome of the development of electro-tinning is the deposition of tin alloys. The first and most striking alloy is Speculum,⁸ containing 45% of tin and 55% of copper. The name derives from the similar alloy used in ancient civilisations for mirrors. Speculum may, perhaps, be most conveniently considered as a superior, but cheaper alternative for silver plate. The colour and reflectivity are very similar, but Speculum is harder and more tarnish-resistant.

80-20 tin-zinc. Note freedom from corrosion products in all but the thinly coated specimen.

Electro-deposited tin. Note severe rusting.

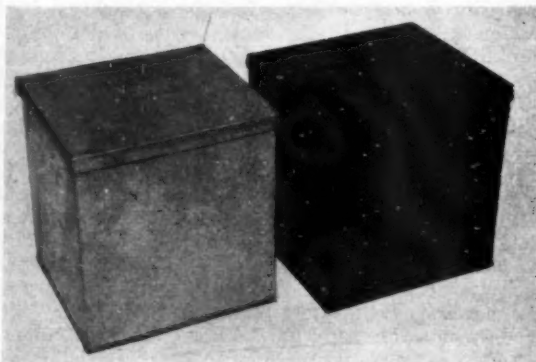
Electro-deposited zinc. Note heavy corrosion products.

Hot-dipped zinc. Note heavy corrosion products.

The broad outline of this process was worked out before the war, but in the recent past, as post-war production has got under way, quite a number of commercial plants have been installed and technical progress has been along the lines of simplifying operational procedure and improving chemical controls. Under present conditions, output from the new plants is not large, but the fact that several firms have extended their plants after a few months of successful operation, is good ground for believing that this finish will take a substantial and permanent place in industry.

The co-deposition of tin and zinc is a more recent development of great promise as a protective and anti-corrosion coating for iron and steel. Alloys of various proportions can be obtained in the form of smooth, tightly adherent coatings.^{9, 10}

Zinc coatings protect the underlying steel by a kind of sacrificial action, zinc being anodic in the zinc-iron couple. The protection is excellent as long as the zinc lasts, but zinc is a somewhat active



Treated can.

Untreated can.

The T.R.I. "Protecta-tin" process has been applied to one of these biscuit tins (made of charcoal, tinplate); both tins were subsequently exposed out of doors for five weeks.

element and it corrodes away rather rapidly. Tin, on the other hand, has a high intrinsic resistance to corrosion, but in the presence of ample supplies of oxygen, it has no sacrificial action. The tin coatings used in industry are usually exceedingly thin, and the underlying steel is liable to be attacked at pores or at points of mechanical injury. The 50/50 alloy, for example, offers a convenient blend of the valuable properties of both its constituents. It has a relatively high inherent resistance to corrosion, and yet it is sufficiently anodic to steel to prevent rusting at pores or points of mechanical injury.

In a comprehensive series of tests in which steel specimens with various protective plated finishes were

7 J. Kronstein, *Jour. Electrodepositors Tech. Soc.*, 1940, Vol. 16.
8 R. M. Anglin, F. V. Jones, J. W. Price, and J. W. Cuthbertson, "The Electrodeposition of Speculum," *Jour. Electrodepositors Tech. Soc.*, 1946, Vol. 21.

9 R. M. Anglin, "The Electrodeposition of Tin-Zinc Alloys," *Jour. Electrodepositors Tech. Soc.*, 1946, 21.
10 R. M. Anglin and R. Kerr, "Corrosion-resisting Properties of Electro-deposited Tin-Zinc Alloys," *Eng.*, March 29th, 1946.

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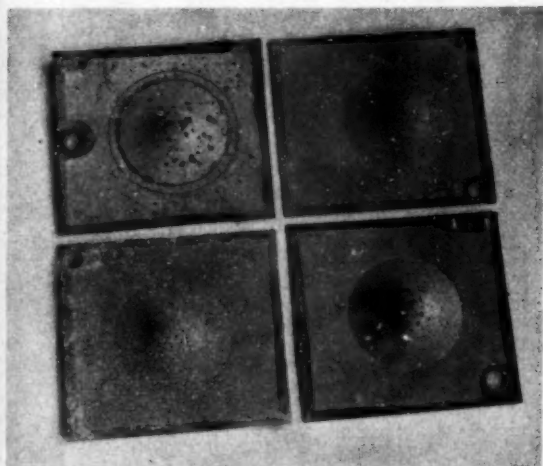
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subjected to several forms of corrosive attack, the tin-zinc alloy coating showed great superiority to tin, zinc or cadmium, used alone. Some idea of the protective qualities and intrinsic resistance to corrosion of the 80/20 alloy coating is illustrated in Fig. 1. This contrasts the result of corrosive attack by salt spray on a tin-zinc alloy coating, and on both tin and zinc coatings used alone. Heavy local rusting has occurred on the tin-coated specimens, while the zinc coatings are almost entirely converted into a whitish corrosion product, and rusting has begun. The tin-zinc coatings, however, are scarcely attacked and no rusting has occurred. Further, it may be seen that a thin coating of tin-zinc alloy has provided better protection than tin or zinc coatings of much greater thickness.

It is important that protective coatings remain reasonably intact when the basis metal has been deformed. Fig. 3 shows steel specimens that have been plated, deformed in the Erichsen cupping machine, and subsequently exposed to humidity tests. The tin and cadmium-coated specimens show rusting. The zinc and tin-zinc alloy coatings do not.

Tin 0.0007 in.

80-20 tin-zinc 0.0007 in.



Zinc 0.0007 in.

Cadmium 0.0007 in.

Fig. 3.

Humidity chamber tests (1,430 hours) on specimens deformed in the Erichsen cupping machine after plating.

The alloy is plated from a solution which is in effect a combination of two well-known baths, and consists primarily of sodium stannate and zinc cyanide. It is simple to operate and the occasional chemical checks are easy. Alloy anodes can be used to replenish the bath.

The deposit, although not recommended as an ornamental finish, is of a pleasing white appearance and polishes with extreme ease to a silvery colour which is retained for a considerable time. It is easy to solder, and coated steel can be spot-welded. It is likely to be adopted wherever improved resistance to corrosion is required and is already being tried out industrially for such parts as radio chassis, window frames, electric water heaters, aero-engines, electrical instruments, and articles of domestic hardware. As it is particularly resistant to salt spray tests, it may have special applicability in naval and marine equipment.

The use of a flux de-gassing process in the manufacture



Bronze strip (5% tin) showing the inferior surface due to tin-sweat as produced before adopting new technique.



Bronze strip (5% tin) showing surface free from defects, produced immediately after adopting the new T.R.I. technique.

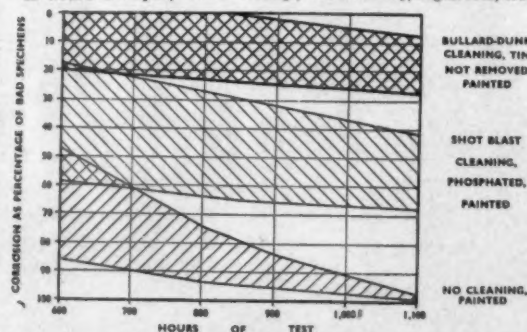
of bronze, has made considerable progress, particularly in the manufacture of billets and sticks cast in metal moulds. A cheap and simple flux consisting only of sodium silicate and copper oxide is recommended, and if used correctly, in conjunction with a final de-oxidising treatment (with phosphorus), and a slow pouring technique, exceptionally dense and uniformly sound metal can be obtained. Current progress is related to methods of mould dressing and core preparation^{11,12} which prevents the formation of secondary types of unsoundness caused by absorption of gas through interaction between molten metal and the mould or core surfaces. These reactions frequently give rise to bad surfaces, and unsoundness of a serious nature, but they can be eliminated by the procedures recently devised.

The chief object of using a mould dressing is to prevent interaction between the molten metal and the mould wall. If the mould consists of copper, copper alloy, or steel, welding may occur between the molten bronze and the mould.

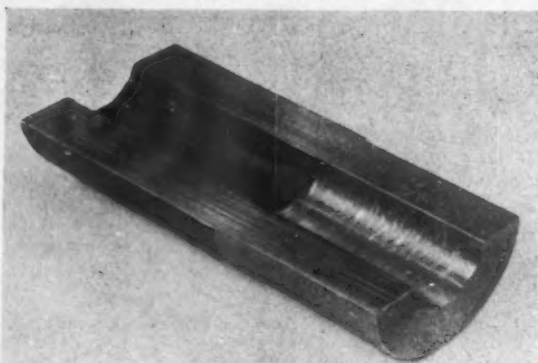
With the commonly used cast-iron moulds, the most usual defect is "blowing." This is the entrapping of bubbles of gas between the solidifying ingot and the mould wall. The chief source of this gas is a reaction between carbon in the cast iron and oxides present

11 W. T. Pell-Walpole, "The Gassing of Bronzes by Reaction with Moulding and Core Sands," *Foundry Trade Jour.*, Jan. and Feb., 1946, and *Jour. of Inst. of Metals*, 1945-46.

12 W. T. Pell-Walpole, "Mould Dressings," *Metal Industry*, August 16th, 1946.



Comparative resistance to corrosion of steel window frames after plating, preceded by different methods of preparation. The shaded areas show the percentage of steel samples which have failed after various durations of the corrosion tests.



Bronze stick (10% tin) cast 36 in. long with new type mould dressing and steel core, showing small machining allowances now required when using the T.R.I. technique.

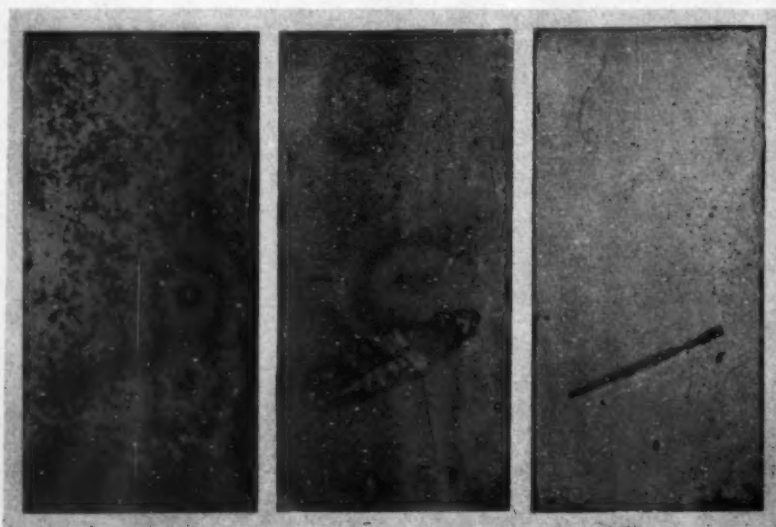
either on the mould surface or in the stream of molten metal. Mould dressings may themselves give rise to defects, the commonest of which is the entrapping of solid particles of carbon or refractory material in the surface of the ingot. The interaction between molten metals, moulds and dressings is exceedingly complex and as casting conditions vary from foundry to foundry, it is not unnatural that each foundry tends to develop a specific dressing to solve its individual difficulties. If, however, the standardised melting and pouring techniques now recommended are adopted, a single type of mould dressing will suffice. After a wide survey, a special type of aluminium paint was found to be the most effective dressing. This paint has sufficient body to provide a barrier between the molten metal and the mould, and is of a consistency that permits a thin even coating to be applied.

The problem of cores called for a different solution. It has been found that all binders used for sand cores are partially decomposed at casting temperatures and liberate sufficient gas to give rise to defects. This can be particularly serious when casting long hollow sticks for bearings. The evolution of gas can be got over by the use of an iron core, but there is difficulty in extracting the core from the casting. This is overcome by wrapping the iron bar with one or more layers of asbestos paper, the number of layers depending on the diameter of the core. A suitable core wash is applied, and the core is baked before use. To remove the core, the casting can be immersed in water, which softens the paper and permits the metal core to be tapped out. A somewhat similar technique has been developed for large cores such as are used in gear wheel blanks. These measures not only facilitate the production of castings with exceptionally high characteristics, but the surfaces are also so free from defects that machining allowances can be substantially decreased.

Cold-drawn bronze tubing is a product that has not hitherto been on the market. The new methods of casting bronze greatly facilitate the production of both hot-worked and cold-drawn products. Condenser tubes of 10% tin bronze were made experimentally before the war and were put into the condenser of a large power station using estuarine cooling water known to be severely corrosive. The tubes have now been in service for seven years and are still in good condition. This experience is reported in a paper¹³ dealing comprehensively with the resistance to corrosion of various bronze alloys in jet-impingent and sedimentation tests. In these tests 10% tin bronze gives a better all-round performance than the alloys now in general use based on cupro-nickel and aluminium brass.

As to the future, the most helpful development would be a restoration of ample supplies of tin obtainable in a free market. The key to the position is the rate at which the Malayan and Netherlands East Indies mine-fields can be restored. This is being prosecuted with vigour and success. The destruction of existing equipment was less than originally anticipated, and in addition to repairs and renewals being effected on site, much new plant is being prepared in England, Holland and America. Current production from the areas liberated from the Japanese is, of course, still small, but as pre-war capacity was some 50% in excess of normal world demands, supplies should balance consumption long before all the damaged plants are fully restored. The official view is that this will not occur before 1948, but official prognostications on rubber production fell so far below actual performance that there are excellent grounds for expecting that before the close of 1947 the supply of tin will be sufficient to meet all the demands of our reviving industries.

13 J. W. Cuthbertson, "The Resistance to Corrosion by Sea Water of Some Tin and Tin-Aluminium Bronzes," *Jour. Inst. of Metals*, 1946, Vol. LXX. 11.



No pre-treatment.

Phosphated.

0.00003 in. tin.

Steel plates painted with air-drying japan after the various pre-treatments indicated above, and subsequently exposed for 1,500 hours to accelerated weathering tests. These illustrations are reproductions of photographs taken after stripping the paint and removing the phosphated coating so as to exhibit the extent of the rusting.

ZINC AND ITS ALLOYS

A Review of Present-Day Uses

By B. Walters, M.A.

In this review the author shows how the change over from war-time to peace-time conditions has affected the various uses of zinc, and discusses certain more recent applications of the metal.

IN Great Britain the transition of zinc and its alloys from war-time to peace-time uses has not been heralded by any spectacular developments, but is the story of the application of lessons learned during the war to peace-time products, and the development of known uses.

In considering this transition it is instructive to compare the distribution of zinc among the various industries over the two periods. For this purpose, four periods have been chosen—namely, the years 1942 and 1943, which were the years of peak war consumption, and the two periods of six months following V.E. day. The percentage distribution of zinc among the various industries is given in Table I.¹

TABLE I.—PERCENTAGE DISTRIBUTION OF ZINC AMONG THE VARIOUS MAIN INDUSTRIES.

Period	Brass	Galvanising	Rolled Zinc	Zn ^o Oxide	Zinc Alloy Die-casting	Zinc Dust	Miscellaneous
1942	59	10.5	6.0	6.4	12.7	1.5	3.9
1943	64	8.0	6.4	7.0	7.0	3.8	3.8
July/Dec., 1945	36	22.7	10.4	17.8	6.0	2.1	5.0
Jan./June, 1946	32	25	9.8	19.8	6.8	2.2	4.4

During the first two periods, brass, due to its importance as a war material, took the lion's share of production, while restrictions in galvanising cut consumption for this purpose to a low value. The increase in 1943 of zinc dust consumption was probably due to the requirements of chemical warfare; the amount of zinc consumed in the die-casting industry was also considerable; this is referred to later in this review.

In the latter two periods, the changing conditions are evident. The consumption of zinc for brass manufacture has dropped to a lower value, but is still considerable, this industry being the largest single consumer of the metal. Galvanising, with restrictions relaxed shows a big increase. The drive to provide houses and furniture and to make good war-time neglect is shown by the marked increase in the consumption of zinc oxide, which, with lithopone is extensively used for paints, linoleum, rubber, etc. With the cessation of war production, the relative consumption of zinc for die castings shows a considerable fall, but it is tending in the last period to increase again.

Zinc Production

In Great Britain zinc is produced entirely by pyrometallurgical processes, electrolytic production carried out in other countries being precluded by high fuel costs and lack of water power. The product is suitable for many purposes, but for special applications, notably alloy production, the impurities lead, cadmium and iron, are removed by a combination of fractional distillation

and refluxing processes, giving the familiar "four nine" zinc of purity 99.99 %. The fume obtained as a by-product is a valuable source of cadmium.

Rapid determination of small amounts of impurities, essential for process control, is carried out by spectrographic analysis. In pre-war days the spectrograph was looked upon with suspicion by many people. To get its acceptance as a standard method of analysis has not been easy; there were many difficulties, such as variation in photographic plates, processing and standards to be overcome, but the method is now firmly established both for the determination of impurities and of alloying constituents.

Zinc Alloys

At the outbreak of war, the Government turned to the zinc pressure die-casting industry for the production of many of the vast number of components required for the Services. This was a bold policy, since it was known that the duties expected from these castings would be heavier than those previously encountered. Confidence in the industry was not misplaced, and a prodigious number of castings were produced, including vehicle parts, gun sights and components, radar equipment and a very large quantity of ammunition parts, many of them of an extremely complex nature. The manner in which these withstood the rough handling inseparable from war-time use, and their behaviour in all sorts of climatic conditions, has given peace-time users added confidence in zinc alloy die castings.

Under the stimulus of war, improved die casting machines and methods were introduced, which have resulted in marked improvements in mechanical properties of die castings as compared with those obtained only quite a few years ago. This is shown in Table II, which compares typical properties of pressure die castings in B.S. 1004 Alloy A (Mazak 3) produced in 1938 and in 1942. Comparative figures after three years normal ageing are also given for castings produced in 1942, and it will be seen that these properties are well maintained on ageing.

TABLE II.—MECHANICAL PROPERTIES OF PRESSURE DIE CASTINGS IN B.S. 1004 ALLOY A—CAST IN 1938 AND 1942.

Date cast	Ultimate Tensile Strength tons/sq. in.	Elongation on 2 in.	Impact Strength ft. lbs.
1938	17.5	3.7	32
1942	18.5	15.2	42
1942—after three years normal ageing	17.0	23.8	40

This improvement in die-casting technique has increased the ability of zinc alloy die castings to withstand shock loading, and has resulted in further application of these alloys to relatively highly stressed components, a practice which some years ago was not

¹ Compiled from Z.D.A. Statistical Review.

regarded with favour. One outstanding example of the use of zinc alloy die castings for highly stressed components is its application to gear wheels, ranging from those used in watches to those used in lawn mowers and small lathes.

In the U.S.A. these alloys find limited application in the extruded form, and it is interesting to note that the impact value of the pressure die-cast material is only slightly lower than that of the material in the extruded form, both tests being conducted on a specimen of the same size. This is surely a great tribute to the pressure die-casting process.

In this country, Government insistence that for Services use die castings shall comply with B.S. 1004, which limits to very small amounts the impurities lead, tin and cadmium, and the excellent service given by these components have brought home to the user the wisdom of having die castings made to this specification, thereby achieving maximum dimensional stability and freedom from intercrystalline corrosion. Failure of die castings due to contamination is now a rare occurrence. Disappearance of this danger has fostered the use of die castings in the tropics. Zinc alloy die castings conforming to B.S. 1004 are quite stable in tropical conditions, and superficial corrosion, which must not be confused with intercrystalline corrosion, can be prevented by "Cronak" treatment, an easily applied chemical dip.

While the casting-in of steel and brass inserts into die castings has been carried out for a long time, fabric and paper inserts are now treated in the same way, the rapid chilling of the casting preventing burning of the material. Such methods are useful for pulleys and other components where special surface properties may be necessary.

It is interesting to note that in Italy, where zinc was the only home-produced metal, zinc alloy in die cast and other forms was used to a comparatively greater extent than in this country. It cannot be said that, given other metals, all these applications were the most suitable, but assessment of the performance data which has not yet been completed will yield further information as to the possible uses of zinc alloys.

The motor industry was one of the first to utilise zinc alloy die casting on a large scale, and is still probably the largest peace-time consumer. In the U.S.A. particularly large radiator grilles are a prominent feature of the latest designs. The complicated and distinctive shapes could not be achieved economically by any other method of manufacture, and their dimensional accuracy greatly simplifies assembly. In Great Britain, although these rather flamboyant designs are not popular, the simpler radiator grilles are also die cast in zinc alloy by several manufacturers.

Advances have been made in finishing methods for die castings, particularly in the field of organic finishes. The use of radiant heat for stoving is still in the development stage, but the shorter time of heating which this method permits should be beneficial in maintaining properties of die castings during stoving treatment, provided that excessive temperatures are avoided.

The zinc alloys, known in this country as K.M. alloy, and in America as Kirksite A, which were originally developed for the manufacture of press tools for the aircraft industry have found new uses for press forming tools for the production of motor-car body steel panels. Their combination of toughness, easy castability and machinability, render them excellent for this purpose.

In addition to their long life they have the advantage that in the early stages of production, where changes in design call for rapid tool modification, such changes can quickly and easily be carried out. The punch, blank holder, and die are all cast from the zinc alloy using plaster patterns, and in many cases are of considerable weight. After use they may be remelted and used to make new tools, the properties of the metal being maintained.

Zinc alloy press tools are also used for the cold bending of light gauge steel tubes, which are first filled with fusible alloy. This method is particularly valuable when the bends are made in more than one plane. Assembly jigs cast from zinc alloys are a common feature in many factories, and, following American practice, these alloys are being employed to an increasing extent in the form of dies for plastic moulding.

In the rolled form K.M. alloy plate has found a peace-time use as dies for the manufacture of light alloy blanks for forming into domestic hardware.

As in the case of die-casting alloys, lead, cadmium and tin must be held at very low values to avoid deterioration of the alloy from intercrystalline corrosion, and precautions must be taken in the foundry to see that such contamination does not occur.

Zinc Sheet

While zinc sheet has a large number of established uses, particularly in the manufacture of cans for dry batteries, mention should be made of its application to roofing.

Zinc roofs are an important architectural feature on the continent of Europe, but in this country the material has not received the attention which it deserves. Zinc sheet is one of the lightest permanent roofing materials obtainable, Nos. 14-16 zinc gauge sheets (0.31-0.41 in. thick) being in common use. After short weathering it forms its own protective coating, and drippings do not discolour woodwork and masonry. It is probable that in this country war-time restrictions prevented its development, and it is likely that its popularity as a roofing material will increase.

Zinc Coatings

The use of protective zinc coatings for iron and steel goes back a long way. The oldest method, hot-dip galvanising, is familiar to everyone, and has returned to its peace-time importance.

Protection by electrodeposited zinc, whereby a thinner coating is applied, is also extensively used, the anodes being high purity zinc. The protection afforded by zinc is sacrificial, and when exposed to the atmosphere, the zinc dissolves very slowly in preference to the iron. For this reason, the degree of protection is determined largely by the thickness of the coating. The application of heavier electrodeposited coatings by the "Tainton" electrogalvanising process, has now found a specialised field in the manufacture of wire ropes,² the process being used as an alternative to hot-dip galvanising.

It differs from the usual electroplating process for zinc in that insoluble anodes are used. The electrolyte is made by the direct dissolution of roasted zinc ore in sulphuric acid, followed by a careful purification process, the cells being operated at a very high cathode current density.

² This is fully described in: "The Tainton Process for Bryanised Wire," H. Roebuck and A. Briery, *Metal Industry*—July 19th, 1946, p. 50-53.

Electrogalvanising gives a ductile, adherent, high purity coating of uniform thickness, and, since it is carried out at room temperature, does not affect the structure of the wire.

Another process,³ still in the development stage, concerns the simultaneous electrodeposition of zinc and tin. The protective action of tin is that of a nobler metal, and corrosion of the base metal takes place at any pores or other defects in the coating. That of zinc is sacrificial, and there is an optimum percentage at about 28% zinc, at which the combination of the two properties gives better protection than that afforded by either metal singly. Similar work is being carried out on the electrodeposition of zinc and nickel coatings.

The value of zinc coatings has been recognised in B.S. 990 (1945) dealing with the construction of metal casement windows and doors, which states that these shall be protected by a zinc coating applied by galvanising, spraying or sherardising.

Of the three, spraying probably offers the greatest advantage in that it is easily carried out, gives good protection and affords a satisfactory base for paint. The wire feed to the spray pistol is made by extruding large billets of 99.99% zinc into $\frac{1}{4}$ in. dia. rod, which is finally drawn into wire; the high purity of the zinc is an additional protection against corrosion. Other spraying methods using zinc powder or molten metal are also used.

More generally, the application of a metallic coating is recommended in a B.S.I. Recommendation, PD. 420 (1945), as a base for paint applied to light gauge and wrought iron products; this applies more particularly to material used in dwelling house construction, zinc being given as the most useful metal for the purpose.

A considerable tonnage of zinc dust is produced annually, which is used in chemical processes, notably dyestuffs manufacture, for sherardising and for paints,

and so the electrochemical protection by paint films; special vehicles are used based on polystyrene or chlorinated rubber.

Evolution of hydrogen by zinc dust paints during storage, mainly due to moisture in the paint media, is prevented by the addition of a little quick lime.

Interesting developments are taking place in the compounding of metallic zinc paints with wholly inorganic vehicles, for example one paint, by the formation of oxychlorides by reaction after painting, dries with a cement like surface.⁵ In Australia good results are reported from a paint based upon a siliceous vehicle, applied to a 240 miles length of above-ground water main.

The use of zinc chromate as a constituent of anti-corrosive priming paint, mainly for light alloys, is well established. Normal production grades are substantially free from soluble chromates and other salts as required by Air Ministry Specifications, and commercial zinc chromate is being rapidly superseded.

A newcomer to this field is zinc tetroxy chromate. B.P. 547859 covering this gives reasons for considering it a true compound $4\text{ZnO} \cdot \text{Zn} \cdot \text{CrO}_4 \cdot 4\text{H}_2\text{O}$, among these being its distinctive X-ray pattern. In the U.S.A. the material is accepted in official specifications in place of the normal chromate, and tests here have shown that its acceptance is well merited. Tests⁶ also show that mixtures of this material with red iron oxide primer have attractive possibilities.

In conclusion the author wishes to thank the Imperial Smelting Corporation, Ltd., for permission to publish this review and members of the staff for their assistance in its preparation.

4 J. E. O. Mayne and U. R. Evans, "Protection by Paints Richly Impregnated with Zinc Dust," *Chem. and Ind.*, March 18th, 1944, p. 109.

5 Iron and Steel Inst., Corrosion Com. Paper No. 12/1943, p. 21.

6 W. W. Kettelberger, "Zinc Tetroxy Chromate," *Ind. Eng. Chem. (Ind. Edn.)* 1942, 34, p. 363.

Zinc in Paints

Zinc and its compounds have three main applications in the paint field, and a number of interesting developments are taking place.

The greatest use of zinc in pigment form continues to be zinc oxide and lithopone, the latter formed by the co-precipitation of zinc sulphide and barium sulphate. A good paint should wear by uniform erosion, as opposed to mechanical failure; periodic repainting will then preserve the priming coat upon which the real protection depends. Zinc oxide and lithopone in equal proportion, compounded with mica or asbestine, form an excellent mixture for use in oil and varnish paints of this nature.

Acicular and leaded zinc oxide, the former made by a controlled oxidation process, the latter by co-fuming of lead sulphate and lead oxide, are less well known. They are valuable as primers, particularly in situations where mould and similar growths may exist.

In the form of metallic dust mixed with a little zinc oxide, zinc is incorporated in anti-corrosive paints for steelwork. Among the more general uses, such paints are extensively used as protective coatings for containers for potable water.

The recent trend is to consider zinc dust as an alternative to metallic zinc coatings where the use of these is impracticable. It has been shown⁴ that very heavy zinc dust loadings improve the electrical conductivity

British Interests affected by Nationalisation in Czechoslovakia and Poland.

THE question for claims for compensation to be awarded to British owners of property which may be affected by the recent nationalisation measures in Czechoslovakia and Poland has been the subject of exchanges between H.M. Government and the Governments of these countries. H.M. Government are now willing to represent such claims to the Governments of Czechoslovakia and Poland. In addition, H.M. Government are willing to receive and forward claims for War Loss and Damage which will be considered by the Polish War Compensation Office.

In order to assist the United Kingdom Representative in making and pursuing these claims, a Register of British property rights and interests in Czechoslovakia and Poland is being established. Accordingly, persons having any assets in those countries should register them. Poland covers the territories at present being administered by the Government of the Republic of Poland.

The Register will be kept in the Trading with the Enemy Department, 24, Kingsway, London, W.C. 2, to which address application should be made for the appropriate forms indicating the class of asset.

3 R. M. Angles, "The Electrodeposition of Tin-Zinc Alloys," *J. Electrodeposition Tech. Soc.*, 1946, 21, p. 45-64.

A Compound Method for the Absorptiometric Analysis of High and Super High-Speed Steels

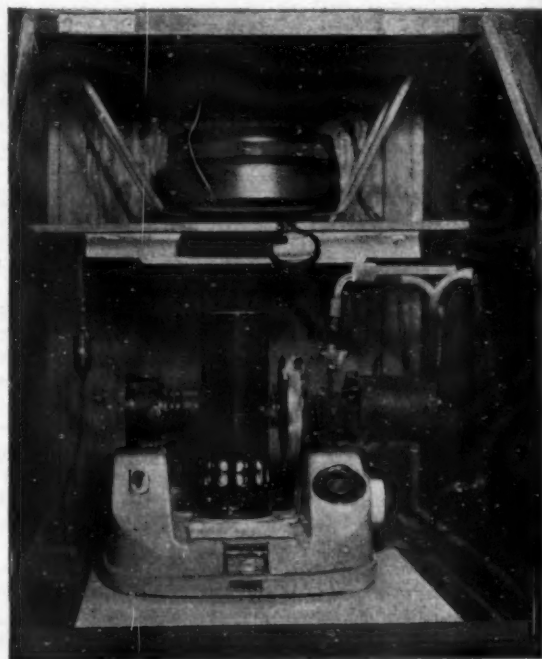
By F. E. Eborall, A.Met., A.I.M.
Chemical Laboratory, Geo. Senior and Sons, Ltd.

Cobalt, chromium, vanadium, nickel, molybdenum and manganese are determined on one sample weight. Tungsten is separated and the adsorbed molybdenum and vanadium separated along with the tungsten, are determined. Other elements are determined utilising modifications of the methods published by Messrs. Vaughan,¹ and Haywood and Wood.² The writer is indebted to Mr. S. Harrison (Messrs. Kayser Ellison & Co. Ltd.), for the modification in the method for cobalt.

WHEN attempts are made to analyse high-speed steels using the normal method of solution in Spekker acid and the methods for chromium and vanadium applicable to tungsten-free steels, interference is found from tungsten which renders these methods useless. Solution in the mixture of sulphuric and phosphoric acids generates, on oxidation, an infinite series of vanado-phospho-tungstates which, being of a yellow-orange colour in the oxidised state and a brown colour in the reduced state, interfere to a high degree with the estimation of the above elements. It has been found impossible to prevent the formation of these compounds by any method applicable to absorptiometric work except by the removal of tungsten from the solution.

This can be achieved by the oxidation of a sulphuric acid solution of the sample and subsequent filtration. However, oxidation with nitric acid tends to leave a proportion of the tungsten in solution and this residue will form the complexes to a lesser extent but still sufficient to give high results. Oxidation with sodium nitrate and subsequent fuming brings down the tungsten with a greater degree of completeness and also does not form any vanado-tungstates. For this reason sodium nitrate has been selected as the oxidant in the method. If complete separation of the tungsten is required, the addition of 3 ml. of 60% perchloric acid, following digestion with sodium nitrate, and subsequent fuming will achieve this result and render the separation quantitative.

High-speed steels, as is well known, contain elements that form carbides of a nature that makes them very resistant to decomposition by chemical methods. In super high-speed steels of the cobalt type, carbide formation is a serious problem to the analyst. In order



The Spekker instrument on which the determinations were made; it will be noted that it is fitted with some unusual equipment.

to accomplish the total decomposition of these complex carbides, fuming to a high degree with sulphuric acid is undertaken, prior to the oxidation. The tungsten in this class of steel may exist as different proportions of: (a) Dissolved tungsten; (b) iron-tungsten carbide and (c) ferro-tungsten. (a) and (b) are decomposed by the initial fuming and on oxidation; (c) presents some difficulty, and only by prolonged digestion following oxidation can complete conversion to tungstic acid be achieved. Digestion following the initial solution also assists in the subsequent conversion. It is not always realised that the annealing temperature of cast samples is of importance to the chemist. Samples annealed above 850° C. are likely to give more trouble than those which do not pass this temperature. An annealing practice which can be recommended to assist the analyst is to heat the sample from the cold to 840° C., soak at that temperature for 10-15 min., cool in air till black and water quench. This treatment will be found to leave the carbides in a form in which decomposition can be achieved with a fair degree of ease. Forged bars and samples which have received a full anneal will show much greater opposition to decomposition.

Separation of the tungsten involves the accompanying of small percentages of other elements, notably molybdenum and vanadium, by adsorption. Up to 5% of the vanadium is adsorbed and on occasions 20% of the molybdenum has been found to remain with the tungsten. In order to overcome this source of error, the precipitate is dissolved in caustic soda, the adsorbed molybdenum recovered and the vanadium estimated. Providing decomposition of the carbides is satisfactory, little or no chromium and cobalt remains, nickel and manganese are also not adsorbed to any noticeable degree.

¹ Monographs by R. J. Vaughan, M.Sc., F.R.I.C.
² Haywood and Wood, Metallurgical Analysis by Means of the Spekker Absorptiometer. Hilger, 1944.

It will have been noticed that much stress has been laid on the need for the decomposition of the carbides. A little patience and care at this stage is amply repaid by the rapidity and accuracy of the methods following filtration. The whole sequence, done singly, should take only 2-2½ hours, and when handled in batches of up to 10, 4 hours should suffice. This compares very favourably with that taken by one man doing the same number of estimations by the classical methods. The accuracy achieved can, in trained hands, be better than that obtainable by any other methods, particularly for cobalt, nickel and molybdenum. The tabulated figures give an idea of what can be achieved on what is well known as a difficult steel to handle.

Nickel is included in this scheme since the writer has found that many high-speed steels, in these days of mixed scraps, contain high percentages of this element and a routine analysis for the same may often serve to prevent later troubles due to its unsuspected presence.

In the cobalt determination, boiling following the addition of sodium acetate has been eliminated. The addition of concentrated nitric acid to a boiling solution was a matter of some danger to the chemist, and it has been found by other workers to be unnecessary. Providing that a period of five minutes is allowed to elapse after the addition of the acetate, colouration of the cobalt complex is complete and decolourisation of the iron complex is achieved in some ten minutes following the addition of the nitric acid. No alteration of the graph has been found necessary following the adoption of the cold method.

Graphs for the compound method are prepared by the standard procedure and knowledge of this is assumed. The graph for the adsorbed vanadium should be prepared from a solution of sodium tungstate to which has been added the necessary amounts of vanadium to simulate that present in the samples (up to 0.1% vanadium on a 0.6 gr. sample), followed by acidification with phosphoric acid and dilution to 60 ml. Since the steels under consideration are of such a highly alloyed nature, the percentage of iron present must be taken into consideration when preparing graphs, particularly in the case of those for chromium and vanadium.

It will be seen that tungsten may be separated on a quantitative basis, and research is proceeding to devise a method of estimating the tungsten. Many reagents have been investigated, but up to the present no method has been found that will give absolutely reliable results. Research is still proceeding, and it is hoped that some method will be found which will complete the sequence of those already in operation.

This compound method is in regular operation on steels of the 18% W., 4% Cr., 1% V. type and also on super high speeds of the 22% W., 13% Co., 5% Cr., 1.5% Mo., 1.5% V. type. Good results are obtained on a routine basis with the saving of much time and labour.

Solutions required.

Sulphuric acid	20%
Phosphoric acid	S.G. 1.75
Perchloric acid	S.G. 1.54
Ammonium sulphate	0.5% Aq.

Sodium acetate	50% Aq.
Nitroso-R salt	0.3% Aq.
Nitric acid	One
Ammonium citrate	50% Aq.
Iodine	N/10
Dimethylglyoxime	0.1% in 50% ammonia
Sodium hydroxide	5% Aq.
Phenolphthalein indicator	
Stannous chloride	10% in 10% HCl
Sulphuric acid—	(10%)
Perchloric acid	(8%)

Analoids required.

Sodium nitrate	0.5 gr.
Silver nitrate	0.08 gr.
Ammonia persulphate	0.75 gr.
Urea	0.5 gr.
Sodium thiocyanate	0.5 gr.
Hyperol	0.5 gr.

Procedure

Mercury vapour lamp used for all readings.—Dissolve 0.6 gr. sample in 36 ml. 20% sulphuric acid contained in a Pyrex or Hysil 200 ml. conical beaker. Digest following complete solution for five minutes. Evaporate to strong fumes and continue fuming at a lower heat for a few minutes. Care must be taken not to over-fume so as to leave insoluble sulphates. Cool, dilute with 30 ml. water and boil. Simmer until all sulphates are dissolved and oxidise with one sodium nitrate Analoid. Digest until all tungsten is a bright yellow and then evaporate to fumes. (If desired, add 3 ml. A. R. perchloric acid before evaporating. This addition will improve the separation of tungsten and enable fuming to be carried out with greater ease). Care must be taken to avoid undue "bumping" at the closing stage of the evaporation. Continue fuming for a few minutes, cool and dilute with 40 ml. water. Filter into a beaker containing 7.2 ml. phosphoric acid. Wash with 0.5% ammonium sulphate. Cool filtrate and reserve for fractionation.

To the original beaker add 10 ml. 5% sodium hydroxide. Dissolve any tungsten adhering to the beaker. Transfer funnel to a clean beaker and pour the sodium hydroxide on to the pad. Wash the beaker and pad with 0.5% ammonium sulphate using small washes so as to keep the total volume under 55 ml. To the filtrate, add a few drops phenolphthalein indicator and neutralise with phosphoric acid, adding 1 ml. excess. Dilute to 60 ml. and reserve.

Fractionation

Main solution.—Take the following fractions:—

50 ml. for Cr-Mn, 5 ml. for Co, 10 ml. for Ni, 10 ml. for Mo, and reserve the balance for V.

Tungsten solution.—Take 5 ml. for Mo and reserve remainder for V.

Determination of chromium and manganese.—Boil the 50 ml. fraction and add 1 Analoid of silver nitrate. Simmer until dissolved and then add 1 Analoid of ammonium persulphate. Allow colour to develop and then boil 2-3 min. Cool; add 1 Analoid urea and dilute to 100 ml. Read on violet filters (Ilford 601) for chromium using 2 cm. cell and a W-W 1.0 setting. Read off graph for chromium figure, applying corrections as below. Read another portion of the same solution for manganese on yellow filters (Ilford 606) using 2 cm. cell and a W-W 1.0 setting. Read off graph for manganese figure.

Determination of cobalt.—To the fraction for cobalt add 30 ml., 0.3% nitroso-R salt and 10 ml. 50% sodium acetate. Stand not less than 5 mins. and add 5 ml. conc. nitric acid. Stand 5-10 mins. (until iron colour has faded), dilute to 100 ml. with distilled water and read on yellow filters (Ilford 606) using 1 or ½ cm. cell (1 cm. up to 6% and ½ cm. above), W-W setting 1.0. Read off graph for cobalt figure. Blank deduction of about 1 drum division will be found necessary.

Estimation of nickel.—To the fraction for nickel, add 30 ml. water, 20 ml. 50% ammonium citrate, 5 ml. N/10 iodine and 20 ml., 1% dimethylglyoxime. Dilute to 100 ml. and read on Ilford mercury green 807 filters, using a 2 cm. cell and a 1.0 W-W setting. Read nickel percentage from graph, correcting as below.

Determination of molybdenum.—Deliver the fraction for molybdenum from the main solution into a flask

containing 25 ml. 8% perchloric acid—10% sulphuric acid mixture, 10 ml. 10% stannous chloride and 1 sodium thiocyanate Analoid. Immediately following this fraction, add the 5 ml. fraction from the tungsten solution to the flask (making a volume of 50 ml. in all). The solutions must be added accurately since no subsequent dilution of the solution is carried out. Dafferts automatic pipettes are recommended. Stand the mixture for 15 mins. and read on Ilford mercury green filters, 2 cm. cell W-W 1.0 setting. Read molybdenum percentage from graph after deducting a blank of 5 drum divisions.

Determination of vanadium.—To the balance of the main solution, add a few drops of saturated pot. permanganate. Stand for 5 mins. in order fully to oxidise the vanadium. Add 1 hyperol Analoid and stand for 20–30 mins. Shake well to release oxygen bubbles and read on violet 601 filters, 2 cm. cell W-W 1.0 setting. Read vanadium percentage from graph, correcting as below. Add figure for adsorbed vanadium as found below to obtain total vanadium.

Determination of adsorbed vanadium.—Stand the balance of the acidified tungsten solution for 30 mins. and read on violet 601 filters, 2 cm. cell, W-W 1.0 setting. Obtain vanadium figure from graph constructed from acidified sodium tungstate solution containing the requisite amount of vanadium. Add figure so obtained to that obtained above to find total vanadium figure.

Difference Method

The methods given above are all direct readings. If it should be desired to operate difference methods for any element, the initial weight should be increased and other reagents and acid volumes adjusted in proportion. Difference methods can be operated with benefit on vanadium and chromium determinations but are unnecessary in other cases. In the case of chromium, the blank for cobalt will be eradicated and in the case of vanadium, the corrections for chromium and cobalt will be unnecessary. The same solution can be used for both chromium and vanadium blanks. The reading for the vanadium blank should be halved for the chromium blank.

A suggested procedure is as follows: 0.75 gr. dissolved in 45 ml. 20% sulphuric acid, given the same treatment as before, and filtered into a flask containing 9.0 ml. phosphoric acid. Dilute to 150 ml. and fractionate as follows: 50 ml. Cr Mn, 10 ml. Mo, 10 ml. Ni, 5 ml. Co, 50 ml. V.

The remaining 25 ml. should be read on violet 601 filters, 2 cm. cell, W-W 1.0 setting. This will give the blank for vanadium, and this reading halved will give the blank for chromium.

The tungsten solution should be diluted to 75 ml.

CORRECTIONS:

Correct for	On	Approx. Correction
Manganese	Chromium	1% Mn = 0.50% Cr
Cobalt	"	1% Co = 0.01% Cr
Vanadium	"	1% V = 0.04% Cr
Chromium	Manganese	5% Cr = 0.02% Mn
Chromium	Nickel	1% Cr = 0.01% Ni
Cobalt	"	1% Co = 0.02% Ni
Chromium	Vanadium	1% Cr = 0.08% V
Cobalt	"	1% Co = 0.01% V
Molybdenum	"	1% Mo = 0.04% V
Range. Using weights and cell sizes given.		
Chromium	0.5–0%	Manganese 0.1–5%
Cobalt	0–13.0%	Molybdenum 0–1.5%
Nickel	0–1.0%	Vanadium 0–1.7%

The vanadium figure will still require to be corrected for molybdenum. If a difference method is applied to the nickel method, erratic results may be obtained since the cobalt correction is derived from the reaction of cobalt with the dimethylglyoxime.

Reproducibility

A set of six complete compound methods was carried out under routine conditions to determine the reproducibility of the method. The following results were obtained. The steel analysed was the well-known Ridsdale W₂ cobalt high-speed standard. The carbide formation of this steel is very resistant to decomposition and examination of the residue following the solution of the tungsten showed that an average of 0.02% vanadium had remained as undecomposed carbide; 0.01–0.03% chromium was also detected on those samples giving lower chromium figures.

	% Cobalt	% Chro.	% Molyb.	% Nickel	% Mang.	% Vanad.
Sample No. 1	4.36	3.35	0.55	0.42	0.23	0.80
2	4.39	3.31	0.59	0.42	0.22	0.81
3	4.36	3.33	0.54	0.42	0.23	0.78
4	4.39	3.31	0.56	0.42	0.23	0.80
5	4.39	3.32	0.55	0.43	0.23	0.79
6	4.39	3.35	0.56	0.42	0.22	0.81
Average	4.38	3.33	0.56	0.42	0.23	0.80
Range (Spekker)	0.03	0.04	0.05	0.01	0.01	0.03
(Standard)	0.21	0.21	0.09	0.05	0.08	0.07
Standard	4.35	3.32	0.55	0.43	0.23	0.82

It will be seen that in many cases that the Spekker range is well within that from which the standard figure is calculated, and in all cases the Spekker figures show close adherence to the average figures shown for the various elements. This is one set of many such, which have been done during the past year and can be repeated at will, proving that the absorptiometer can be applied to this class of steels with accuracy and confidence.

Thanks are due to the Directors of Messrs. Geo. Senior & Sons Ltd. for their permission to publish this paper and to Mr. H. H. L. Lockley, A.Met., F.I.M., for his support and encouragement.

Equipment for Royal Train

SOUTH AFRICAN PHILIPS (PTY.), LTD., of Johannesburg have asked Philips Industrial (Philips Lamps), Ltd., of London, England, to supply 16 motor generator sets to South African Railways and Harbours. They are for installation on South African railways, two of them being for the Royal Train, which will be used by Their Majesties the King and Queen when they visit South Africa early in 1947. These latter sets will supply all the current necessary to operate the radio transmitters and receivers installed, and are required to be interference-free on all frequencies. They will be controlled by an ordinary tumbler switch in the radio cabin.

Two trains, each of 14 coaches, will make up the Royal entourage. One will be a pilot train to precede the Royal Train and will accommodate Government and Railway officials and the Press. It will be in constant and direct radio communication with the Royal Train. The pilot train will be equipped with high-speed short wave radio transmitting apparatus, and Keying equipment and a short-wave radio receiver.

THE HOFFMANN MANUFACTURING CO. LTD. have opened a new branch office at 59, Queen Square, Bristol, 1, which will be under the control of a qualified ball and roller-bearing engineer. The telephone number is "Bristol 20561."

The History and Present Status of Emission Spectroscopy as Applied to Industry—III

By John Convey, F.Inst.P.

In this, the concluding part, the author discusses the photometry and calibration of spectrograms, and refers to some of the efforts made to effect direct intensity measurements of spectral lines. In recent years spectral excitation methods have improved and photo-multiplier tubes, with greatly increased sensitivity, have become commercially available.

SYNONYMOUS with the growth of spectral excitation control is the design and production of spark stands whereby the electrodes for analysis are held. Although many novel spark stands are found in many laboratories the mention of three types will show the growth of spark stand design. Fig. 17 illustrates the simple arc and spark stand as used in many British laboratories. Unfortunately this stand cannot withstand the high voltage and amperages of some of the modern source units and a new type was developed by Vincent and Sawyer

Gramont, and spring-loaded stands of Vincent and Sawyer, together with appropriate insulation, safety switches and filter screens for the observation of the arc or spark discharge without injury to the operator.

The Photometry and Calibration of Spectrograms

From the preceding parts of this article the reader learns that a qualitative spectrochemical analysis is based

of luminous atoms in the source of light and the number of luminous atoms is proportional to the aggregate number of atoms in the sample. Fig. 20 illustrates how the characteristic line densities of certain atoms change in agreement with the variations in composition of a series of standard steel alloys.

One of the earliest methods developed for the quantitative interpretation of emission spectra is known as the comparison method. The procedure is to compare the density of an analysis spectral line with the density of the same line in a series of adjoining spectra of standard samples. Modifications of this method have been developed whereby a comparison of the density of the analysis spectral lines with that of another

line occurring in the same spectrogram. This procedure eventually led to the "internal standard" method developed by Gerlach and Schweitzer.⁴³ This procedure is to determine the relationship between the concentration of an element to the intensity ratio of a

⁴³ Gerlach, W. and Schweitzer, E. "Foundation and Methods of Chem. Analysis by the Emission Spectrum." A. Hilger, Ltd., London.

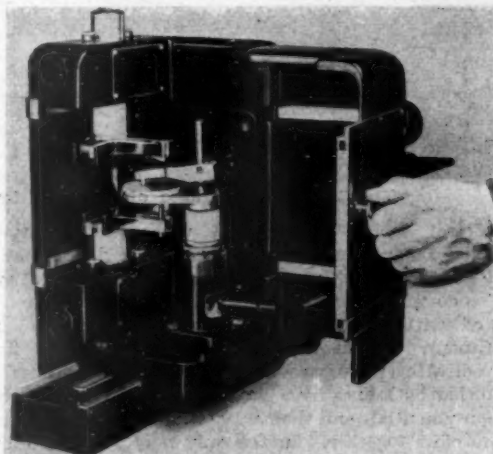


Fig. 19.—The A.R.L.-Dietert universal arc and spark stand.

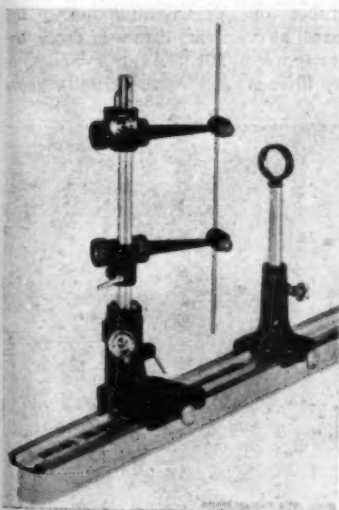


Fig. 17.—The Gramont arc and spark stand.

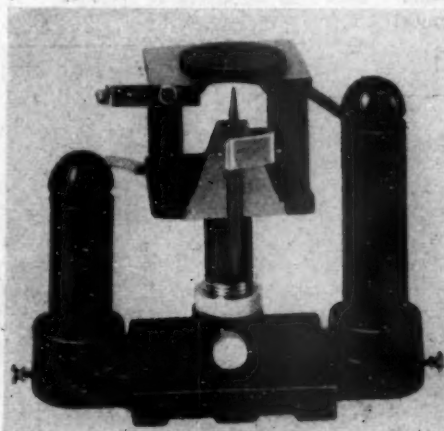


Fig. 18.—The Petrey spark stand.

and also by Scribner. For ease of operation when flat specimens are to be analysed the Petrey stand, as illustrated in Fig. 18, was produced.

To-day, there exists the A.R.L.-Dietert universal arc and spark stand whose main features are illustrated in Fig. 19. This stand possesses all the good features of the Petrey, De

upon the fact that every atom, when rendered luminous, emits certain invariable spectrum lines which are characteristic of the specific atoms. Spectroscopists soon recognised that quantitative analysis could be obtained from observations of the intensities of spectral lines. The intensity of the spectral line depends upon the number

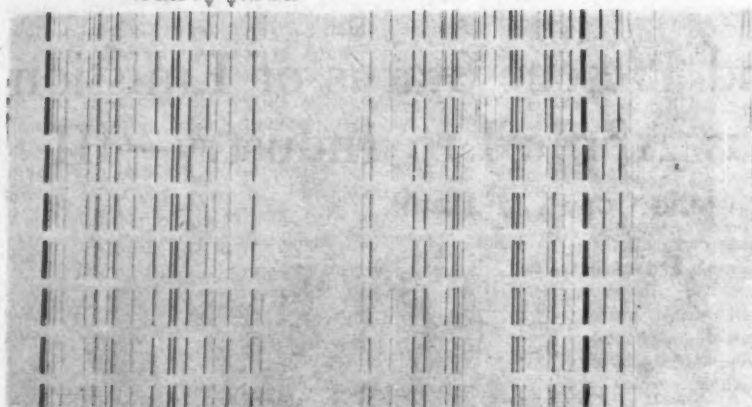


Fig. 20.—Spectrograms of standard low alloy steels.

spectral line of the element under analysis and a line of another element present in known amount. The comparison line is usually associated with the major alloying constituent. The choice of the analysis spectral line pairs is usually determined so that both lines have similar excitation potentials and their wave lengths are close together. In this way it is assumed that the internal standard method will correct automatically variations in excitation, exposure and errors in response of the photographic plate. Unfortunately, the choice of such homologous pairs of spectral lines is not always practicable. However, the method has been quite successful and is adopted in most spectrochemical procedures to-day.

As every quantitative spectrographic determination is dependent upon a quantitative measurement of an intensity ratio it is evident that remarkable progress in quantitative analysis resulted from the development and application of microphotometers. Several commercial models of microphotometers are available. Modern non-recording instruments provide for (1) a manual then mechanical sweep of spectra thus making the reading of spectral line densities objective and not subjective, (2) a wide field of view for easy identification of selected spectral lines, and (3) provision for reference spectrograms in conjunction with the analysis of spectra. In

addition, recording instruments are available, particularly the Leeds and Northrup Model. Figs. 21 and 22 illustrate the non-recording Dietert and the Leeds and Northrup recording microphotometers, respectively.

Until a few years ago, intensity ratios were interpreted directly as photometric deflection ratios. This procedure was possible by restricting all photometric measurements to the approximately straight line portion of the H and D curve of the photographic plate. This method is still used by most British laboratories. In this manner "working curves" showing concentrations plotted against spectral log intensity ratios are obtained.

Fig. 23 illustrates a working curve for the determination of manganese in low alloy steel. However, investigations of spectrographic errors indicated that the error associated with the photographic plate could be reduced when the photographic emulsion was calibrated in terms of relative intensities. Various methods of emulsion calibration have been developed and used in spectrography. The methods originally used were the inverse square, the step wedge or step filter, and the step sector method. The inverse square method consists of preparing a number of spectrograms using the source at various distances from the spectrograph slit. A step wedge or step filter is used for the simultaneous



Fig. 21.—The A.R.L.-Dietert non-recording microphotometer.

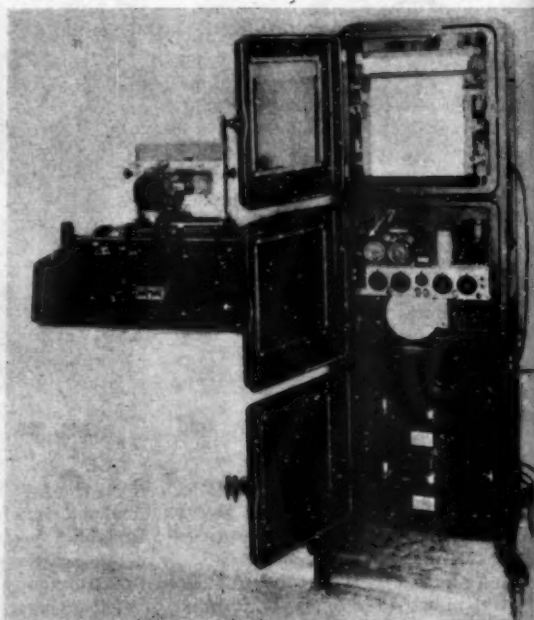


Fig. 22.—The Leeds and Northrup recording microphotometer.

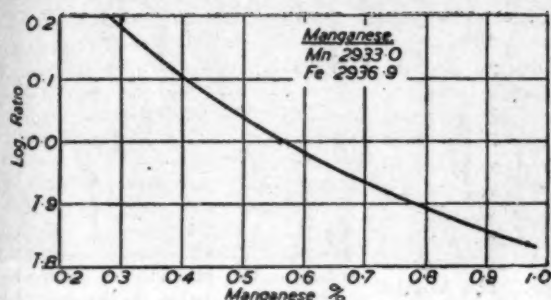


Fig. 23.—Manganese calibration curve.

production of a number of exposures of known relative intensities. In the step sector method a series of calibration spectrograms is produced simultaneously through the use of a rotating disc having a series of graduated stepped apertures, the sector is placed in front of the slit.

At a later date, a method for plate calibration was developed, primarily by Dieke and Crosswhite.⁴⁴ This method involved the application of groups of previously calibrated standard iron lines, and its use indicates the modern trend of spectrochemical analysis wherein theory and practice of spectroscopy are both used. The chosen standard lines usually originate from the same upper energy atomic level and are thus independent of excitation variations. This method is superior to the previously mentioned step sector

technique and is generally used in most up-to-date laboratories to-day. A modification of the method has been devised by Churchill⁴⁵ of the American Aluminium Company, wherein he uses only two lines which bear a fixed ratio of intensity to each other, usually between 1.2 and 2.0. A number of microphotometer readings of this pair enables one to produce a calibration curve for a particular emulsion.

Direct Recording of Spectrochemistry

Occasionally errors occur due to the non-uniformity of spectral plates and films, hence one can expect that attempts at the direct intensity measurements of spectral lines have

⁴⁵ Churchill, G. R. *Ind. Eng. Chem. (Anal. Edit.)*, 16, 11, 653. (1944.)

⁴⁴ Dieke, G. H. and Crosswhite, H. M. *J. Opt. Soc. Am.* 33, 8, 425. (1943.)

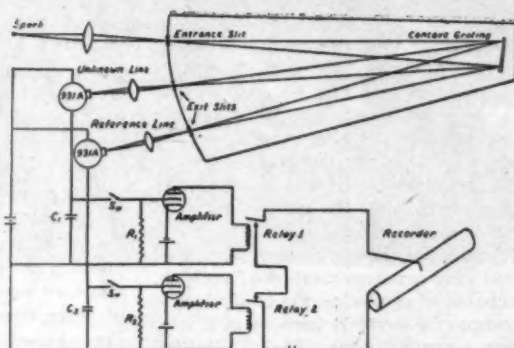


Fig. 24.—Direct recording system.

been made for several years. Originally the spectral sources employed in spectrographic analysis lacked control of spectral excitation and the phototubes that were available for radiation detection were too insensitive. In recent years spectral excitation methods have improved to a large extent and photomultiplier tubes with greatly increased sensitivity have become commercially available. The tubes are so arranged that sensitive spectral lines of the elements to be determined are incident via suitably placed slits on the cathodes of the electron multiplier photo-tubes. Appropriate amplifiers and electrical computing circuits measure the intensities of the respective spectral lines. Fig. 24 illustrates the principle of the direct recording method as employed by

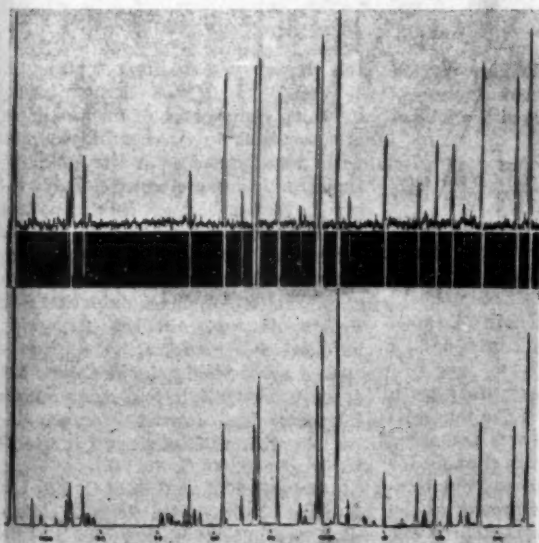


Fig. 25.—Part of iron spectrum. Middle: Reproduction of spectrogram. Upper: Microphotometer trace of spectrogram. Lower: Direct photo-electric recording.

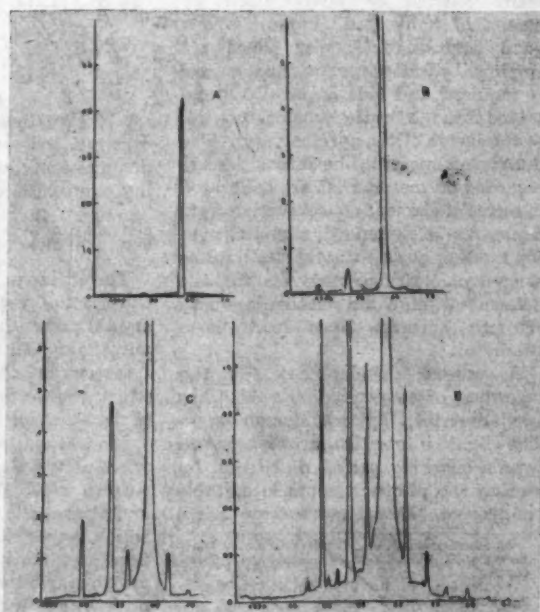


Fig. 26.—The 4358 mercury line recorded with different sensitivities.

Saunderson, Caldecourt and Peterson.⁴⁶

This advance has opened up new possibilities and should produce the answers to many of the problems confronting the industrial spectroscopist. It eliminates the procedures and errors associated with photography, photometry and the interpolations of concentrations from calibration curves. In addition, it is an extremely rapid and very sensitive method of analysis, capable of producing the analysis of a sample for several elements in a very few seconds.

The application of the photo-multiplier tubes to spectrophotometry was described by Harrison⁴⁷ in 1939. In spectrochemistry Boettner and Brewington⁴⁸ in 1944 applied a direct reading method to quantitative spectrographic analysis. Hasler and Dietert⁴⁹ produced the direct reading spectro-quantometer and recently Nahstoll⁵⁰ and Saunderson⁴⁶ have described the successful application of the method as a foundry control.

Up-to-date, most of the direct-reading of spectral line intensities has been associated with gratings instruments. Hasler and Dietert use stationary recorders and the accommodation of several multiplier tubes on the focal curve of the spectrograph is obtained by deflecting the selected lines by mirrors on to the entrance slits of the multiplier tubes. The fixed positions of the detectors are easily located or interchanged by means of calibrated screws. When fixed position multiplier tubes are employed effective temperature control is required and this is usually maintained through the thermostatic control of the inside of the spectrograph. The integrated spectral line intensities are recorded on meters that are calibrated in terms of element concentration from exposures of standard samples with the reading of an internal standard as a control. Bridge methods for the determination of the relative intensity of two spectral lines have been produced.

A unique development for the recording of concentration values has been described by Saunderson *et al.* The light intensities are integrated over a sparking period of 20 secs. by storing the photo-currents in suitable condensers. Direct current amplifiers

of novel design measure the stored charges, and the results are recorded on a strip chart of electrical marking paper. The lengths of the recorded lines give a measure of the time interval required for the condensers to discharge from their initial voltage down to some small value. One of the condensers is charged by the photo-current from an internal standard spectral line. The lengths of these lines are directly related to the concentrations of the respective elements in the sample under analysis.

To avoid the extra precautions and difficult set-up of fixed photo-tube recorders Dieke⁵¹ uses one or more movable slit and tube combinations which scan the spectrum and register the spectral lines successively. Fig. 25 illustrates an interesting example of the results given by Dieke. A comparison is shown of the photographic and direct-reading methods of spectrum recording.

Suitable amplification of the photo-current makes possible the recording of very faint lines in a few seconds that would require hours to record photographically. Fig. 26 illustrates the recording sensitivity of the photo-tube method where records are shown

⁵¹ Dieke, G. H. and Crosswhite, H. M. *J. Opt. Soc. Am.* 35, 7, 471. (1945.)

Thermal Treatment of Chromium-Molybdenum-Aluminium Steel, 38 KhMYuA

By I. E. Brainin

AN investigation has been carried out on two chromium-molybdenum aluminium steels of the following compositions:

C	Mn	Si	Cr	Mo	Al	P	S
0.37	0.51	0.26	1.51	0.24	0.97	0.015	0.020
0.24	0.54	0.24	1.43	0.22	0.73	0.020	0.013

The object of the work was to study the effect of preliminary heating on the crystal growth, mechanical properties, and the appearance of a "stone-like" fracture in the 38 KhMYuA steel which has a composition corresponding to those investigated.

It was found that the crystal growth was a direct function of the temperature to which the steel was preheated and a parabolic function of the time for which it was exposed to any one temperature. An intensive growth of the grains started at 1,000° C. There was no relation between the preliminary heating and the impact strength. The smaller the McQuaid-Ehn grain size,

From *Stal*, 1945, 5, pp. 67-77.

of the sixth order ghosts of the mercury line 4358A as well as the weaker lines 4348, 4339 and 4344A.

The errors associated with this direct method are source control response differences between individual photo-tubes and the ageing of the tubes. However, these errors do not appear to be too difficult to reduce considerably. The success of the photo-tube spectral intensity recorders has been so remarkable in the past few months that it appears to be destined to play a major part in the future of industrial spectrography.

With this very brief account of the establishment of spectroscopy in industrial laboratories, the author hopes that the reader can appraise the necessity for the collaboration of spectrochemists, in order to compare and evaluate different opinions on the subject. The inauguration of the Industrial Spectroscopy Group of Great Britain should provide a means for the increased organisation of spectrochemical knowledge, also a headquarters for future meetings, when results can be compared and relevant factors collected. Although each of the members may not contribute original work, all can be enthusiastic and the success of the group will be judged by the whole-hearted co-operation of its members.

the greater was the impact strength.

Steel 38 KhMYuA heated in an oxidising atmosphere of furnace gases is susceptible to overheating coupled with development of a "stone-like" fracture. It is therefore essential to install in the furnaces optical pyrometers for better control of the temperature. Isothermal tempering after the stamping (substituted for annealing) saves fuel and reduces oxidation and decarbonisation. As the tempering temperature increases, the tensile strength and yield point decrease, but relative elongation and compression increase. The impact strength increases with the tempering temperature up to 250° C.

Between 300° and 500° C. lies the interval of impact brittleness. Generally, as the temperature increases up to 500° C. the mechanical properties change little. Above 500° C. the strength declines but the elasticity improves.

⁴⁶ Saunderson, J. L., Caldecourt, V. J. and Peterson, E. W. *J. Opt. Soc. Am.* 35, 11, 681. (1945.)

⁴⁷ Harrison, G. R. *Proc. 6th Summ. Conf. Spectro.*, p. 91, M.I.T. (1939.)

⁴⁸ Boettner, R. A. and Brewington, G. P.

J. Opt. Soc. Am. 34, 6. (1944.)

⁴⁹ Hasler, M. F. and Dietert, H. W. *J. Opt. Soc. Am.* 34, 751. (1944.)

⁵⁰ Nahstoll, G. and Bryan, F. R. *J. Opt. Soc. Am.* 35, 10, 646. (1945.)

MICROANALYSIS

CHEMICAL AND PHYSICAL METHODS

APPARATUS

METALLURGICAL APPLICATIONS

TECHNIQUE

IT is a common belief that if one meets an unusual word in the course of one's reading, it has a way of appearing twice more in quick succession. There is rather more experimental support for the apparently coincidental recurrence of topics. Topics have a way of being "in the air." Such has been our experience in the past few days concerning the education of scientists and others. This has cropped up, for us, in a public lecture, in a debate, and in several private conversations. In every case the view was expressed that the general run of non-scientific people must be made au fait with the implications of science—science, in other words, must be popularised in some way. But the striking point is that in every case the reciprocal view, that students of science must have their educational basis broadened, was also put forcibly. It is very true that specialisation, which is so much on the increase, tends to deny to science students the opportunity to study and to practise their own language and literature. As a consequence, their writing on scientific subjects is cribbed, stilted, or what is more to be deprecated, though less obvious, jargon. It cannot be brought home too strongly to students, and indeed, to all chemists, that in the last analysis their efficiency depends on the ability to read and write—to read thoughtfully and to write wisely and well.

Applications of Metallurgical Microchemistry to the Light Alloy Industry

Part I—Production Control

By Donald F. Phillips,

Chief Chemist, Research Laboratories, Messrs. High Duty Alloys, Limited

Microchemical analysis can be applied to light alloys in two directions, one of these is concerned with control, while the other is concerned with special analyses which do not form a part of the routine. The ways in which the problems are met are naturally different in the two branches. In this first article, the application to routine work of small scale methods is described, and this will be followed later by a description of the more specialised applications.

FOR the purpose of this review metallurgical microchemistry will be defined as any analytical procedure which is carried out on a scale smaller than that usually employed in orthodox analytical practice.

In the light alloy industry chemical analysis may be classified under two broad headings.

- (1) Production Control of Aluminium and Magnesium Alloys (Routine Analysis).
- (2) Special and Investigational Analysis.

The former of these will be dealt with in this article, while the latter will form the subject of a later section.

At the present time almost 100% composition control of the light alloys manufactured in two large works of Messrs. High Duty Alloys, Ltd., is accomplished by a judicious combination of spectrographic, absorptiometric, and polarographic systems of analysis.

It is claimed that spectrography is true microchemical analysis, as probably less than one milligram of sample material is consumed in a complete analysis, whilst the absorptiometric and polarographic

procedures in use require smaller samples than are used in classical chemical determinations for the same elements. In general the sample weights employed are one tenth of those formerly employed, although in a few cases rather larger samples have been found more convenient. Such procedures may therefore be regarded as semi-micro.

The successful development of such improved processes has occupied a period of several years, and it is by no means claimed that finality has yet been achieved, or indeed ever will be. However, throughout this period certain terms of reference have always been kept well in view. These are listed below:—

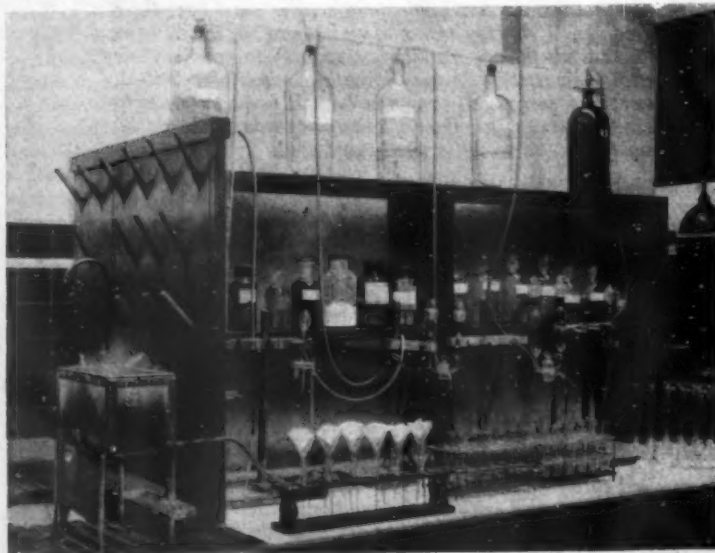
- (1) Adequate precision and accuracy for controlling alloys within specification limits.
- (2) Direct methods eliminating so far as possible tedious chemical separations.
- (3) Rapidity.
- (4) Economy in space utilisation, consumption of reagents and glassware.

- (5) The use of precise instrumental measurements.
- (6) Processes capable of being operated by personnel having no previous analytical experience, after a relatively short training period.
- (7) The freeing of operatives from much of the drudgery of mass routine macro analysis, leading to improved health and general efficiency. This implied that procedures should be elegant in conception, and have a distinct aesthetic appeal to assistants.

Certain details in regard to the different systems in use are discussed below.

Spectrochemical Analysis

At present three Hilger and one Zeiss medium quartz spectrographs are employed in High Duty Alloys laboratories for control analysis. In addition a further Hilger medium quartz spectrograph is reserved for investigational and special work.



Layout for the μ mi-micro processing of aluminium alloy samples prior to absorptiometric determination of magnesium by the titanium yellow process.

The technique employed is one of comparison between the samples being analysed and standard samples of a similar known composition. The comparison is made by measurements of the blackening of selected lines in the spectra of the samples.

The spectra are photographically recorded from a "simple" condensed spark struck between electrodes consisting of die cast pencils of the alloys under test, which have been machined to a standard shape and size. Strict adherence to fairly straightforward conditions of sample preparation, sparking technique, and plate development, yields results having an average accuracy of 5% of the content determined. Evaluation of the spectra is made through the well-known method of the "internal standard" in which the intensities of the unknown lines are compared with those of adjacent lines due to the dominant element (in this case aluminium). This method obviates the apparently unavoidable inaccuracies which result from a series of spectra not having the same level of intensities throughout.

In practice up to 80 spectra are recorded on one plate including the standards which cover the specification range of the elements being determined.

The blackenings of the selected lines are measured in each spectrum on the usual type of non-recording microphotometer, and recorded as galvanometer deflections. The ratios of these deflections are calculated by slide rule for each spectrum. Using double logarithmic paper the values of these ratios for the standards are plotted against the known percentage of constituents to give the standard graphs. Finally the percentages corresponding to the deflection ratios for the samples being analysed are read directly from these graphs.

Other techniques for the evaluation of spectra are in use elsewhere, but the "internal standard" method has so far been adhered to in the laboratories under review, and has been applied to the determination of up to six elements in a range of ten alloy compositions.

The approximate limitations of the system in regard to maximum permissible concentrations of constituents of aluminium alloys which may be evaluated with sufficient precision are given below:—

Copper	0.2%
Magnesium	2.0%
Silicon	1.5%
Nickel	1.5%
Iron	1.5%
Manganese	1.5%
Titanium	0.3%
Zinc	0.3%

It is probable that future research will considerably increase the above limits, thus widening the scope of spectrochemical analysis.

A further advantage is that each spectra may be visually "policed" for the presence of undesirable impurities including lead, tin, cadmium, antimony, bismuth, chromium and calcium, and in practice it has been found that intelligent operators soon acquire the art of visually estimating the concentrations of such impurities, and these estimates when checked by chemical methods have shown a surprisingly close agreement.

At one of the works where spectrochemical analysis is in operation, approximately 75% of the whole composition control is accomplished by this means, and it is expected that this will be increased in the near future.

Development work in hand will, it is anticipated, lead to an extension of spectrochemical analysis to the magnesium base alloys.

Other applications of the spectrograph will be mentioned in a later section of this article.

It should be noted that all the requirements outlined earlier in the article have been fulfilled; in particular the rapidity by which a team of two operatives are able to carry out up to 360 determinations per day. Consumption of materials is limited to photographic plates, developing solutions, and double logarithmic graph paper.

Absorptiometric Analysis

Absorptiometric analysis may be defined as procedures by which chemical contents are determined through measurements of light absorption using instruments previously calibrated against standard solutions.

It was decided to investigate such procedures very



Part of spectrochemical laboratory showing Zeiss medium spectrograph, Feusner spark generator, and Hilger microphotometer.

thoroughly before applying them to production control analysis, and initially a Zeiss Pulfrich photometer was used. Determination of iron in aluminium alloys was chosen as the first investigation, and the colour reaction based on thiocyanate was selected. From the outset it was resolved to aim for a straightforward technique, avoiding so far as possible such complicated operations as extraction of colours with organic solvents and measurements at elevated temperatures, because it was realised that impending war conditions would probably necessitate the recruitment of untrained personnel in order to overcome manpower shortages, and that such operatives would only respond to intensive training schemes if the methods were simple, direct, and did not require too critical optimum conditions. These desiderata called for patient investigation of many hundreds of samples using varying techniques. Eventually a suitable procedure was evolved using a 100 mg. sample, thus reducing the scale of the process to one tenth of that formerly employed. In all subsequent absorptimetric methods this scale has, wherever practicable, been adhered to.

The Pulfrich photometer, although an excellent instrument in the hands of a qualified worker, is subject to rather serious personal errors, and when applied to routine control the precision of the results suffered due to the inability of certain assistants to make the individual adjustments necessary to obtain an exact matching of the brightness of two semi-circles of light viewed through parallel telescopes. Severe eyestrain was sometimes experienced after prolonged periods of using the instrument.

These difficulties were overcome by the introduction of the Spekker photo-electric absorptimeter, which is an objective instrument. How successful this change proved may be judged from the fact that six Spekker absorptimeters are now in use in Messrs. High Duty Alloys.

In due course semi-micro absorptimetric procedures were introduced for determination of copper, nickel, silicon, titanium, manganese and magnesium. The last named is based on the 'Titan yellow procedure of Stross¹ and permits of a precise determination of magnesium being carried out within 20 minutes on a single sample.

Experience has shown that it is generally preferable

to develop simple direct methods for individual elements rather than comprehensive schemes covering the determination of several elements on a single sample weighing, because in dealing with a large number of routine tests little saving is shown if they involve complicated separations, and a large amount of apparatus. In the case of copper, nickel, and iron in aluminium, however, three aliquots are taken from the single solution derived by dissolving the original 100 mg. sample, as the procedure is identical for each of these elements up to the stage of adding the appropriate colour developing reagent.

Where any separations may be essential as in the case of magnesium determination using Titan yellow they are accomplished by centrifuging rather than filtration, the advantages of which are too well known in micro and semi-micro manipulation to require further emphasis.

The colour developing reagents employed for the seven constituents of aluminium alloys determined absorptimetrically are listed below.

Copper	Sodium diethyldithiocarbamate.
Nickel	Dimethylglyoxime.
Iron	Potassium thiocyanate.
Magnesium . .	Titan yellow.
Silicon	Ammonium molybdate.
Manganese . .	Potassium periodate.
Titanium . . .	Hydrogen peroxide.

Here again, the advantages originally aimed at have been achieved, in particular the use of smaller apparatus consisting in the main of 100 ml. tall-form beakers, and 50 ml. centrifuge tubes accommodated in neat copper racks which can be transferred directly to water baths for heating; the 100 ml. Nessler jars ranged in wooden racks, all make for reduced breakages of glassware, and generally serve to create a pleasing visual impression.

"Flow through" cells avoid delays due to filling, and splashing of cell windows, and permit measured solutions to be immediately exhausted to waste by the aid of a filter pump.

Resultant economies through the adoption of these methods have been approximately 50% in personnel, and 75% in reagent consumption over macro methods previously used.

Sample weighings are carried out on Oertling aperiodic prismatic balances, type 52/GB having a sensitivity of 1 mg., and these have proved extremely reliable, rapid, and of sufficient precision.

Similar methods are now being introduced for determining the constituents of magnesium alloys, and so far these are proving equally satisfactory.

Polarographic Determination of Zinc

As yet no satisfactory absorptimetric procedure has been developed for the determination of zinc in aluminium alloys, but the very straightforward polarographic procedure of Stross and Osborn² has been applied with success, and has entirely superseded the tedious gravimetric and volumetric methods formerly in use. It is hoped shortly also to carry out polarographic determinations of zinc in magnesium alloys.

The polarograph would seem to offer attractive potentialities for the analysis of micro samples, and this is discussed in a later article.

REFERENCES

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- 2 Stross and Osborn, "Determination of Zinc in Aluminium Alloys." *Light Metals*, 7, July, 1944, pp. 323-327.

Microchemical Devices—IX

A Micro-Stirrer for Enclosed Systems

By J. T. Stock and M. A. Fill

THE apparatus shown in Fig. 1 was developed in connection with the investigation of the oxygen uptake of certain essential oils, of which only "smelling samples" (i.e., about 0.5 ml.) were available. It should, however, be useful for other semi-micro-scale investigations which involve the stirring of a closed system.

The time-honoured method of magnetic operation is used, originality lying chiefly in the method of securing the pulsations. To the upper end of stirrer A is attached a light glass sealed capsule which contains a light armature in the form of a tube of tinplate. When current passes through solenoid B, which is wound with about 300 turns of 26 S.W.G. insulated copper wire, the armature and attached stirrer is lifted, to fall again when the flow of current ceases. The extent of the stroke can be adjusted by sliding the solenoid up and down on the head tube C of the reaction vessel D. Six-volt supply, drawn either from accumulators or from a mains transformer, gives satisfactory results.

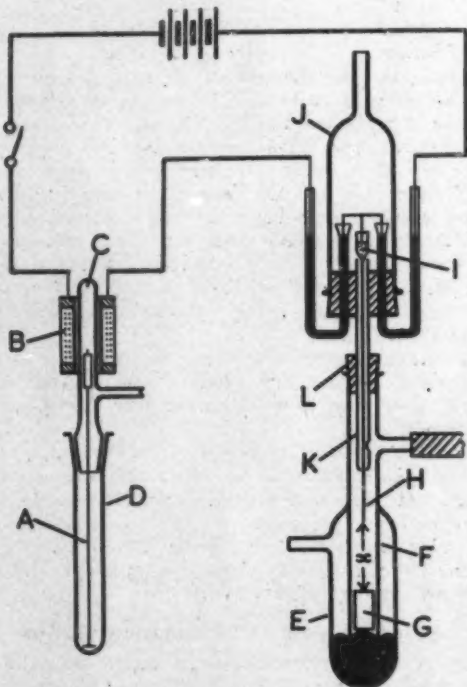


Fig. 1.—Apparatus for electromagnetic stirring.

A circuit make-and-break operated by water-pump suction is used. This device is a modification of a unit originally designed for micro-stirring¹, and its operation depends upon the oscillation of mercury in the annular container E. The oscillation is maintained by the automatic build-up and break of vacuum. When suction is supplied, the mercury rises within the inner tube F, carrying with it the hollow cylindrical glass float G. The latter then strikes the lower end of the valve-rod H with force sufficient to open the valve I against atmospheric

¹ Fill, M. A., and Stock, J. T., *Analyst*, 1944, **69**, 212.

pressure. Entry of air from contact chamber J rapidly destroys the vacuum, so that the mercury within F descends, carrying with it the float, valve-rod and valve. The latter then closes and the cycle of operations is repeated some three to four times per second. The valve lift, which should be about 5 mm., is controlled by the distance (x) (measured when the mercury is in its rest position, as shown). This is adjusted by sliding guide sleeve K, the upper end of which acts as the seating for the valve, within rubber stopper L.

An enlarged view of the contact system is shown in Fig. 2. An M-shaped contact of stiff nichrome, or better, platinum, wire is cemented into the hollow valve head. One leg of the "M" is longer than the other and is arranged to dip into the right hand mercury cup even when the valve is at the top of its stroke. The shorter

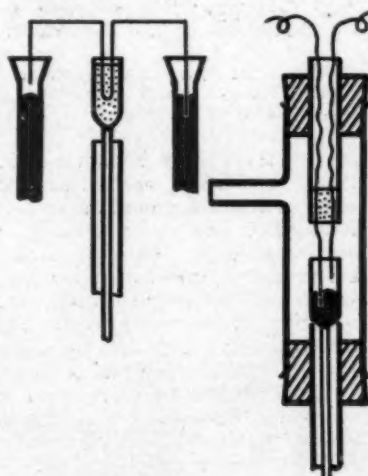


Fig. 2.—Details of contact system.

Fig. 3.—Alternative contact system.

leg is then about 3 mm. above the surface of the mercury in the left hand cup, but dips into the mercury when the valve is closed. Breakage of the circuit thus occurs every time the valve opens. At the same time a puff of air is drawn past the mercury cups and into the interior of the apparatus. Fumes of mercury caused by sparking are thus prevented

from entering the laboratory atmosphere.

Another form of contact system is shown in Fig. 3. This is more compact, but since the circuit is broken as the valve closes, the puffs of air do not synchronise with the production of sparks. In this design, a bead of mercury is placed in the valve head and the contacts are pieces of 24-g. platinum wire. After attaching to copper connecting leads, the contacts, which must not touch one another, are cemented into the lower end of a piece of glass tubing,² so that one contact projects about 5 mm. more than the other. A wide glass tee-piece and two rubber bungs cut from heavy-walled tubing enable the contacts to be supported so that both dip into the mercury when the valve is lifted; when the valve is closed only the contact with the greater projection should remain immersed in the mercury.

² Fill, M. A., and Stock, J. T., *Analyst*, 1944, **69**, 180.

MR. HERBERT FRANCIS is retiring from the Board of Kayser, Ellison & Co. Ltd. after 67 years service with the firm. He was awarded O.B.E. Civil Division for his assistance to the Ministry of Supply, particularly through his knowledge of the adaptability of special steels.

SIR EDWARD HOARE, Bt., has joined the Board of Directors of New Metals and Chemicals, Ltd.

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METALLURGICAL DIGEST

Aluminium Alloy Bearings for Heavy-duty Applications

By H. R. Clauser

UNTIL about 1937, the use of aluminium-base alloys for bearings was generally restricted to those applications involving service under light loads against hardened shafts with good lubrication. Early developments in Britain and Germany followed the classical bearing metal theory of a heterogeneous structure consisting of hard crystals in a soft matrix, and early aluminium bearing alloys contained combinations of copper, iron, silicon, nickel, manganese, antimony and cobalt to provide the hard load-supporting crystals. More recent German aluminium bearing alloys not only had hard particles but also a hard aluminium matrix, and in Britain aluminium alloys containing concentrations of tin up to 26% with smaller amounts of copper, nickel, manganese, antimony and magnesium were experimented with and used with reasonable success for connecting rod and main bearings in high speed internal combustion oil engines.

In the United States experimental work has sought to develop aluminium alloy bearing materials for use as solid bearings, steel-backed aluminium bearings, and powder aluminium alloy bearings. The first two have advanced to a point where bearings are now being commercially produced and are in service. Powdered aluminium bearings are still in the early experimental stages and are not as yet under production. During the war, self-lubricating powdered aluminium bearings were developed equal in performance to self-lubricating bronze bearings. At present, however, such bearings are not applicable to high-duty service because of their high cost and the difficulties entailed in their production.

In the first stage of extensive development work conducted by the Aluminium Co. of America, the alloy-

TABLE I. MECHANICAL PROPERTIES OF HOLLOW CYLINDRICAL PERMANENT CASTINGS OF ALUMINIUM-TIN-SILICON-COPPER BEARING ALLOY.

Property	Cast Heat-Treated	Cast Heat-Treated and Cold Worked (4-1% Axial Reduction)
Tensile Strength, Tons per sq. in.	9.8	10.3
Yield Strength in Tension, Tons per sq. in.	4.0	7.8
Elongation on 2 in., %	10	7
Yield Strength in Compression, tons per sq. in.	4.0	7.6
Brinell Hardness	45	50
Rockwell "H" Hardness	75	90
Shear Strength, Tons per sq. in.	6.5	—
Endurance Limit (500,000 cycles), Tons per sq. in.	4.2	—

ing of tin with aluminium was found to improve the antifriction and corrosion resistance of aluminium satisfactorily, but such superior properties were only obtainable at the expense of the fatigue resistance and load carrying characteristics. By the addition of small amounts of other alloying elements, it was found that under certain conditions sufficient mechanical strength for internal combustion engine applications could be obtained and at the same time satisfactory conformability and embeddability characteristics could be retained. Two alloys were thus developed, one containing 6.5% tin, 1% nickel and 1% copper and the other 6.5% tin, 2.5% silicon, 1% copper and 0.5% nickel. The mechanical properties of an aluminium-tin-silicon-copper bearing alloy are given in Table I and may be considered as typical for the two alloys.

The ability of these aluminium alloys to resist corrosion and seizure under emergency conditions of metal-to-metal contact and thin-film lubrication has been found to be as good as tin-base and lead-base white metals. A test to determine the relative endurance of the cast aluminium-tin-copper-nickel alloy as compared with

steel-backed 65/35, copper-lead alloy and steel-backed tin-base white metal has shown the aluminium alloy to be definitely superior. Aluminium bearing alloys have also excellent corrosion resistance properties against the organic acids and have proved to be equal to silver and tin-base white metal, copper-lead and cadmium-silver bearing metals in this respect.

In the production of solid bearings with these alloys, the permanent mould casting method is generally used. The minimum section thickness possible is 0.25 in. Connecting rod and crankshaft bearings for service in heavy vehicles and aircraft are made with as thick a section as possible for optimum strength and fatigue resistance. Experimental work in manufacturing aluminium alloy bearings by die casting has shown definite promise, and some experimental work has also been done to find a satisfactory rolling practice for producing aluminium alloy sheet for bearing applications.

The antifriction characteristics and corrosion resistance of steel-backed aluminium bearings are similar to those of the solid aluminium type, and therefore are at least as good as the other conventional bearings, such as copper-lead, silver, and tin and lead-base white metals. When the binary aluminium-tin alloys are used, 6 to 10% tin, the antifriction characteristics are superior to the solid aluminium bearing alloys, and a desirable property is their comparatively soft matrix, 30 to 35 Brinell. The strength and fatigue resistance of steel-backed aluminium alloy bearings, which is dependent on the steel backing as well as on the bond between the aluminium alloy and the backing material, has proved to be satisfactory under severe operating conditions. Steel-backed aluminium bearings have also proved to be particularly applicable in installations requiring thin wall bearings.

Two fabricating methods are presently being used for steel-back aluminium bearings. In one procedure, steel tubes are cut to length and the

From *Materials and Methods*, 1946, Vol. 24, No. 3, pp. 633-636.

aluminium alloy cast against the prepared steel surface, either on one or both sides of the steel backing and on the ends, if desired. The shells with the aluminium lining are subsequently machined and used as rounds or split for the manufacture of bearing halves. A similar procedure is used for bushing

or flanged bearings. In the second method, aluminium bearing material is bonded to the steel backing, either on one or both sides, in sheet or strip form. The bearings are then formed from the flat stock by any of the usual metal forming processes and machined to the desired dimensions.

The Boron-Oxygen Equilibrium in Liquid Iron

By G. Derge

METALLURGISTS have used borax as a fluxing agent traditionally, but until recently elemental boron has played an insignificant role as an alloying element. Neither the metal nor its compounds have been regarded as important metallurgical materials and there is a surprising lack of knowledge concerning their metallurgical behaviour. The new applications to steel-making of both boron and borates, which arose in part from war incentives and restrictions, have been seriously handicapped by this lack of data. Experiments were therefore carried out to establish the boron oxygen relations in liquid iron and to demonstrate at the same time the ferroboration slag compositions in equilibrium with various amounts of oxygen in liquid iron.

Slags containing varying proportions of iron and boron oxides were held in contact with molten iron, and samples of both slag and metal were analysed. No entirely suitable refractory was found for these mixtures, but by using rotating technique, short runs could be made in both silica and magnesia crucibles. Silica crucibles gave the least experimental trouble and most of the work was done with these, but since the slags picked up silica from the crucible and some silicon was introduced into the metal from the same source, several heats were also made in magnesia crucibles to avoid difficulties in interpretation that might arise from the presence of silicon. In the apparatus used, crucibles were heated by means of an induction furnace.

A 1,600 gram metal charge was completely melted, rotation was started at 190 r.p.m., and the previously mixed slag ingredients were added slowly. After 10 minutes metal samples were taken off by suction, the power turned off, and samples of both

metal and slag taken from the solidified material. Data obtained from a series of runs made at 1,560° to 1,660° C. show no significant differences with regard to temperature. Slags were prepared by mixing varying amounts of Fe_2O_3 and B_2O_3 , but since ingot iron is highly oxidised, the final slag compositions were always much lower in B_2O_3 than the initial mixture owing to pick-up of iron oxide from the metal. Metal samples were analysed for oxygen, boron, and silicon, and slags were analysed for B_2O_3 , silica, and total iron.

From the results obtained, curves were plotted showing the percentage of B_2O_3 in slag versus percentage of boron in metal, the percentage of B_2O_3 in slag versus percentage of oxygen in metal, the percentage of oxygen in metal versus percentage of boron in metal, the percentage of boron in metal versus percentage of silicon in metal, and the percentage of boron in metal versus percentage of oxygen in metal. The data obtained from silica crucibles showed that the deoxidising power of boron was comparable to that of silicon and could be expressed by the constant—

$$K_s = \frac{1}{\frac{\text{B}_2 (\% \text{ liquid Fe}) \times 0.8 (\% \text{ liquid Fe})}{\text{Liquid Fe}}} = 2.4 \times 10^5$$

This value of K_s was the average of 24 heats that were made in silica crucibles. The average for 14 heats made in magnesia crucibles was 34.7×10^5 , while the average for all heats was 14.3×10^5 .

In the experiments it was observed qualitatively that all of the slags used were very fluid even well below the melting point of iron. The experiments also indicated that by using proper oxygen control it should be possible to introduce a specified amount of boron into steel by a ladle reaction with borax, which would, generally be a cheaper process than the use of expensive ferro-alloys. Such a treatment

Rationalisation in Swedish Mining and in Ore Dressing

IN Sweden considerable attention is being given to the possible results of rationalisation and two reports have recently been published, dealing with investigations on mining and on ore dressing, which indicate that important economies can be effected by adopting rationalised methods. In the first report¹ an introduction is given which indicates the economies and technical conditions which have made rationalisation in mining more and more important. The development is then discussed in detail. The increasing use of improved drilling machines and of hard metal bits is emphasised. The different mining methods, especially sub-level stoping, horizontal cut and fill, sub-level caving and block caving, are discussed. Transport and loading problems have lately been the object of much interest, and the use of mechanical equipment is rapidly increasing. The paper deals among other things with chutes and chute gate constructions, mine cars, mechanical loading, and hoisting, and the author emphasises the importance of large units of cars, chutes, loaders, etc., and also the advantage of placing large breakers under ground for the reduction of sizes of lumps instead of block-holing. Drifting with different cuts, raises, shafts, etc., are discussed. According to a calculation, certain modifications of the mining at the Kantorp mines will give a reduction of workmen employed from 74 to 46 for an output of 150,000 tons of iron ore a year.

In the second report,² which concerns ore dressing, a short review is given of recent developments in respect of machinery equipment in Swedish dressing plants, while some of the problems associated with ore dressing are discussed. Then results are given of a series of tests with ball mill grinding, which illustrate the influence of ball size on grinding effect as well as on the quality of the ground material.

¹ Stellan Anestad, *Jernk Annal.*, 130, 1946, 319-368.

² Sture Mortzell, *Jernk Annal.*, 130, 1946, 369-458.

From *Metals Technology*, 1946, Vol. 13, No. 5, and *A.I.M.E. Tech. Pub.*, 3004, pp. 1-15.

The metallurgists want to get concentrates which are both richer and more coarse-grained. From this has arisen the problem of locked particles of magnetite ores, which has led to thorough studies of the liberation properties in comminution of different ores, comprising among other investigations systematically arranged and evaluated elutriation analyses, which have proved to be valuable when it is also required a numerical basis for estimating the feasibility of obtaining coarse grained, rich concentrates. Examples are given of such ore-dressing which is effected by combining concentration in jigs or shaking tables with magnetic concentration.

The phosphorus content of certain ores can be considerably reduced by intensive concentration, and experiments were also made with leaching in

acids. For the elimination of pyrrhotite from certain iron-ores, flotation of the pyrrhotite at a very low pH has given good results.

After a discussion of supervision and control of operation and indication of some principles for the planning of ore-dressing plants, all of which is of great importance to rationalisation, the author gives data of several Swedish iron-ore dressing plants. A comparison of these data shows which rationalisation measures have been taken during recent years. Furthermore, some particulars of effects and mean values of some other data are given, which may, on the one hand, be regarded as representative of Swedish iron-ore dressing and, on the other, are of importance for judging the degree of rationalisation achieved by the ore-dressing plants.

Relationship between the Deep Drawing Properties of Automobile Body Sheet, its Austenitic Grain Size, and McQuaid-Ehn Carburising Characteristics

By K. J. B. Wolfe

DURING a press run of automobile steel blanks a batch of material will sometimes give very poor results. Failure of such material generally occurs by splitting immediately after the punch has started to form the blank. This effect is specially accentuated in intermediate forming operations on double action press work, and in some extreme cases the metal does not appear to have extended at all before fracture has occurred. It would therefore seem that the metal has behaved as if it were a brittle material. Chemical analysis, microexamination, tensile and ductility tests fail to give any indication for the cause of these failures.

From a study of press conditions it was considered that the high striking velocity of the punch on the blank would tend to cause rupture of the metal under conditions comparable with those present in an impact test involving both tension and bending stresses. The effect of austenitic grain size and carburised microstructure on the impact properties of metal of composition similar to that used for automobile body steel has been studied, and it has been shown that in general a steel possessing a large austenitic grain size with a normal carburised structure will give lower

impact test values than will a steel of similar composition which possesses a small austenitic grain size in conjunction with an abnormal carburised structure. As a result several samples from varying batches of material which had consistently given bad and good results respectively in pressing were carburised and the resulting austenitic grain size and microstructures determined in order to ascertain if such a relationship existed in automobile body sheet.

The various steels, Table I, were carburised at $927^{\circ} \pm 5^{\circ} \text{C}$. for 8 hours, using "Eternite" as the carburising compound, and after carburising, the

box was removed from the furnace and allowed to cool freely in air, the time taken to reach room temperature being about 6 hours. This technique gave a well developed laminated structure in the pearlite grains surrounded by well defined envelopes of cementite, and a microexamination showed the sheets to be carburised right through. The Timkin number of the austenitic grain size was then determined by comparison with standard charts, together with the McQuaid-Ehn carburising characteristics, Table I. All the steels had yield points varying from 8 to 14 tons per sq. in., maximum stresses varying from 18 to 24 tons per sq. in. and elongations greater than 35%.

The results obtained from the various tests showed that automobile body sheets which possessed satisfactory chemical and mechanical properties but had poor deep drawing properties on certain intermediate forming operations, possessed a large austenitic grain size. Sheets which gave good deep drawing results under similar circumstances were found to possess a small austenitic grain size. In addition, sheets which showed poor pressing properties had a "normal" McQuaid-Ehn characteristic, while sheets which showed good pressing properties had an "abnormal" characteristic.

From these results it is postulated that the austenitic grain size depends on the distribution of the carbide particles in the sheets, and it is considered that these particles are the governing factor, as the standard of freedom from non-metallic inclusions in this type of steel is extremely high. It therefore appears that the austenitic grain size and consequently the pressing properties of the sheets probably depend on the amount of carbide

TABLE I. CHEMICAL COMPOSITION, AUSTENITIC GRAIN SIZE, AND MCQUAID-EHN CHARACTERISTICS OF SHEETS TESTED.

Mark	Country of Manufacture and Method of Manufacture	Pressing	Composition			Timkin No.	McQuaid-Ehn Characteristic
			C	Si	Mn		
1 G	British, normalised ..	Front fender	0.05	0.02	0.28	7	Strongly abnormal
1 B	British, normalised ..	Front fender	0.04	0.01	0.25	1-2	Very slightly abnormal
2 G	British, normalised ..	Tonneau side	0.04	Trace	0.21	Rim 3-5 Core 7	Fairly abnormal
2 B	British, normalised ..	Tonneau side	0.04	0.01	0.27	Rim 2-3 Core 4	Strongly abnormal
3 G	British heavy reduction	Screen opening	0.06	0.03	0.25	5-7	Strongly abnormal
3 B	British heavy reduction	Screen opening	0.04	0.02	0.29	1	Slightly abnormal
4 G	U.S.A. heavy reduction	Front fender	0.03	0.01	0.23	6	Strongly abnormal
4 B	U.S.A. heavy reduction	Front fender	0.03	0.01	0.25	1-2	Slightly abnormal
5 G	U.S.A. heavy reduction	Body side ..	0.02	0.03	0.24	—	—
5 B	U.S.A. heavy reduction	Body side ..	0.04	Trace	0.20	2-3	Very slightly abnormal
6 G	U.S.A. heavy reduction	Main floor ..	0.03	0.02	0.26	6-7	Slightly abnormal
6 B	U.S.A. heavy reduction	Main floor ..	0.02	0.04	0.23	2	Normal

From *Amer. Soc. Metal.* 1946, Preprint No. 27, pp. 1-16.

segregation in the ingot in addition to the mechanical and heat treatments which it receives during manufacture. A sheet which has a well dispersed and consequently small sized carbide

phase, will in all probability possess a smaller austenitic grain size than will a sheet in which this phase is not so well dispersed but is consequently larger in size.

A Sulphur Print Method for the Study of Crack Growth in the Corrosion-Fatigue of Metals

By R. C. Brumfield

A NEW procedure for studying the corrosion-fatigue of metals is described, based on the art of making and analysing contact sulphur prints. The corrosion-fatigue machine used was of the operating beam type and operated at 1,425 r.p.m. Weights on the loading rack induced a uniform bending moment in the specimen over the working section, and as the spindles rotated, the material in the specimen was subjected to a sinusoidal stress variation. The spindles rotated in unpacked journal bearings, lubricated by a gear oil pump. Drawbars held the specimen into accurately mated tapers and effected an excellent seal against seepage through the spindles. The rotating seal was formed by spring-loaded bakelite tubing pressing against the ends of the spindle, and the corrosive medium was circulated through the gland with a squeegee pump. The specimens, which were of constant diameter (0.30 in.) in the centre section were carefully polished and the fillets protected from corrosion by a coat of varnish with a serrated edge. This protected the specimen from breaks at the fillet and at the edge of the varnish.

Twenty S.A.E. X 4130 steel specimens were damaged at four different stress levels for various periods of time in order to obtain a good distribution of data over the important regions on the normal stress versus time at stress curve. Some were run to destruction, while others were only partially damaged. Damaged specimens were carefully cleaned to remove corrosion products and the characteristic corrosion fatigue cracks examined, after which the ends of the specimens were trimmed smooth. A fine cutting tool was then used to remove the metal on the surface down to the bottom of the deepest pit and the new cylindrical surface made smooth with emerypaper before sulphur printing. Each specimen was later cut to

successively smaller diameters, in small steps, and a sulphur print made after each cut.

In preparing sulphur prints the prepared specimens were washed in alcohol, dried, soaked in concentrated hydrochloric acid for 30 to 40 minutes to open up the cracks, washed, dried, soaked for 45 minutes or longer in a water solution of sodium sulphide (1 part of $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O} + 2$ parts distilled water), quickly dried, and the sulphur printing paper applied. The resulting sulphur prints gave a permanent record of the minute details of the crack pattern in the various specimens.

After completion of the printing operations, series of sulphur prints made at successively greater radial

depths were mounted and photographed. Deep cracks which remained on prints made at the greater depths were selected for study and the lengths of the crack arcs were measured from the photographs and the crack angles calculated. From the crack angles and the various depths, crack profile curves were plotted on polar diagrams.

A study of the crack profile curves and of the sulphur prints obtained shows that corrosion-fatigue cracks assume a wide variety of shapes and depths of penetration. At least two factors tend to produce variations in crack distribution and growth: 1. Corrosion pitting is almost unpredictable in nature and under corrosion-fatigue conditions lends a wide variety to the sizes, depths, and distribution of pits from which cracks grow. Extreme care should therefore be exercised in duplicating experimental conditions and in testing as many specimens as possible. 2. The process of crack growth is an unstable one. The greater the depth of the crack, the greater is the rate of its growth, and the smaller its depth, the smaller the rate of growth. By limiting specimen damage to crack depths of not more than 25% crack growth can almost entirely be avoided.

Investigation of the Wear of the Rolls During Hot Rolling of Wire and Strip

By Rune Tosterud and Erik Stenfors

THE reasons for changing grooves in rolling are defects of form and surface defects. Defects in the form of the groove are a consequence of normal wear. Surface defects are caused by unsuitable material in the rolls. Methods are given in this report for measuring the wear of grooved rolls and plain rolls for strip, as well as for checking surface roughness and surface defects. The size and form of the worn grooves are registered photographically. The accuracy of the methods of measurement is discussed. These methods make it possible to analyze the influence of different factors upon wear. Thus a rectilinear relation between maximum radial wear and the quantity of rolled material is shown to exist. The prerequisite for this is that the coefficient of friction is constant during the different stages of the use of the groove. It is shown that this prerequisite holds, the reason being that the surface of the groove,

which originally has a good polish, becomes roughened when the first few rods have been rolled. After that the surface roughness remains nearly constant.

To enable comparisons between wear under different conditions, the concepts "relative wear" and "coefficient of wear" are introduced. "Relative wear" is defined as the quotient of maximum radial wear in μ and the corresponding rolled length in kilometer. For rolls with grooves, in which the length of the rod depends solely on the weight of the rolled material, the "coefficient of wear" can be expressed as the quotient of maximum radial wear in μ and the amount of rolled material in tons.

The results of the investigation, which are shown in the form of formulae and graphs, may be of use in planning a rolling mill for a given production or when buying new rolls. An approximate estimate of the rate

From *Amer. Soc. Testing Mats.* 1945, Vol. 45, pp. 545-553.

From *Jernk. Annal.* 1946, 130, No. 6, pp. 213-238.

of replacement can then be made from them. Furthermore the resistance to wear in different materials for rolls can be quantitatively compared by

means of the given methods, which it is hoped will be conducive in bringing about swifter results in the testing of new materials for rolls.

Critical Points of a Nickel-Chromium-Molybdenum Steel as Determined by the Dilatometric Method

By D. Niconoff

BECAUSE the concept of the critical points of metals originated in the days of constitutional diagrams, there is a tendency on the part of metallurgists to consider these values from the static viewpoint. Every steel is expected to have a very definite, if not constant, set of the A_c and A_r temperatures, at which the allotropic transformations occur, and the fact that these temperatures, particularly the ones obtained on cooling, are appreciably affected by the rates of temperature change, is not sufficiently emphasised. It was with the object of determining the effect of variation in rates of temperature change, as well as of some less evident factors, that this investigation was undertaken. The dilatometric method was employed exclusively instead of the metallographic methods which are commonly used in this type of work.

The material used in the investigation was a hot-rolled 1 in. round of S.A.E. 4340 steel, having the composition 0.382% carbon, 0.22% silicon, 0.65% manganese, 1.79% nickel, 0.79% chromium and 0.26% molybdenum. The austenitic grain size of this steel, as shown by the McQuaid-Ehn test, was 6-7 on the A.S.T.M. scale. Test specimens 3 in. long by $\frac{1}{2}$ in. diameter were chromium plated electrolytically to prevent their scaling during subsequent heating to elevated temperatures. After plating, they were uniformly subjected to a preliminary normalising treatment consisting of heating to 870° C. for 1 hour and air cooling. On heating, the specimens became coated with a tight adhering green layer of chromium oxide which prevented them from further oxidation and scaling under conditions of temperature and time involved in the tests.

To ascertain the effect of variation in heating rate upon the position of the A_c and A_r critical points, six specimens were heated at constant rates varying from 5.6° to 220° C. per

TABLE I
RESULTS OF THE VARIOUS TESTS.
Effect of Variation in Rate of Heating upon the Position of A_c and A_r Critical Points.

Heating Rate °C.	Critical Points °C.	
	A_c	A_r
Per hour		
5-6	705	768
10	719	778
40	728	781
95	731	778
180	728	775
220	728	763
Fast at varying rate	728	763

Effect of Previous Heat-Treatment Upon the Position of A_c and A_r Critical Points.

Previous Treatment	Heated at 56° C. per hour		Heated Fast	
	A_c	A_r	A_c	A_r
Normalised	725	781	728	763
Water Quenched	708	770	723	761
Spheroidized	725	783	725	775

Effect of Soaking Temperature and of Duration of Soaking Upon the Position of the A_r and A_c Critical Points.

Soaking Temp. °C.	Soaking Time Hours	Critical Points °C.		Hardness Rc.
		A_r	A_c	
840	0-5	686	610	16-3
840	11-0	665	594	—
760	0-5	790	646	15-2
925	0-5	683	588	22-0

Effect of Cooling at Different Rates Upon the Position of the Critical Points.

Cooling Rate ° C. Per hour	Critical Temperatures °C.				Hard- ness Rc
	Pearlite Range		Brimite Range		
	Ar ₃	Ar ₁	Ar ₃	Ar ₁	
5-6	494	663	—	—	13-2
7	489	656	—	—	14-0
10	479	644	—	—	14-9
40	465	622	—	—	16-3
95	456	644	455	399	29-8
180	—	—	460	389	31-8
220	—	—	471	389	33-6
Furnace	—	—	477	389	32-9
Air	—	—	432	409	34-8

hour, and one specimen was also heated at the maximum rate attainable with the furnace. Under the latter conditions the rate of heating was variable, changing from 60° C. per minute through the 315° C. range to 30° C. per minute through the 704° C. range. These results, Table I, were obtained for specimens which had been subjected previously to a normalising treatment. To determine the effect of prior structure, two specimens were water quenched from 840° C., and two others were spheroidized by heating for 4 hours at 705° C. Their critical points were

determined under conditions of heating at 40° C. per hour and at the maximum rate respectively, Table I.

To establish the effect of the preliminary soaking, so far as both time and temperature were concerned, one specimen was heated to 840° C. for 11 hours instead of the usual 30 minute period, and two others were soaked at temperatures 84° C. both above and below the generally employed temperature. In all instances the subsequent cooling was carried out at 56° C. per hour. The effect of variation in cooling rates upon the position of the A_r points was determined by cooling a number of specimens at constant rates varying from 5.6° to 220° C. per hour, and also cooling in the furnace and in air. All the data pertinent to this series of tests and to the soaking tests are also given in Table I.

The results obtained from the various tests showed that the A_c critical points of a nickel-chromium-molybdenum steel are appreciably affected by the prior structure as well as by the rate of heating. The effect of the prior structure was best noted under conditions of relatively slow cooling, when it reaches a difference of 17° C. between the quenched and spheroidised structures. Accelerated heating rates increased the A_c temperature obtained for slow heating by as much as 22° C. In the case of the A_r point, maximum increase was obtained at intermediate rates, and heating at excessively high rates depressed this point to a value slightly lower than the original temperature.

The A_r points were affected by variations in cooling rates even to a greater degree. The transformation of austenite to pearlite occurred at the 725° to 610° C. range under conditions of cooling below 56° C. per hour rates. When this rate was exceeded, the first evidence of the split transformation was obtained and bainite began to appear. With still further increase in cooling rates, the pearlite region rapidly diminished and the bainite zone grew equally fast, extending at its maximum range from 520° to 365° C. obtained for air-cooled specimens.

The soaking temperature and time appeared to be factors in determining the position of the critical points, and both of them worked in the direction of dissolving residual cementite, thereby destroying the nuclei and consequently depressing the transformation temperature. By plotting

From Amer. Soc. Metals, 1945, Preprint No. 19, pp. 1-17.

the critical temperatures as obtained under conditions of uniform soaking upon the semi-logarithmic time-

temperature co-ordinates, two zones were obtained in which the transformation of austenite took place.

New Age-Hardening Stainless Steel

By T. C. Du Mond

A NEW precipitation hardening stainless steel of the 18-8 type, known as Stainless "W," has been developed during the last few years by the Carnegie-Illinois Steel Corporation, but details of it have been kept secret until recently. A typical analysis of this steel shows it to contain 0.07% C, 0.50% Mn, 0.010% P, 0.010% S, 0.05% Si, 7.0% Ni, 17.0% Cr, 0.7% T and 0.2% Al. The composition is balanced so as to ensure, without the necessity of cold working, the almost complete austenite to ferrite transformation and the subsequent precipitation hardening. Titanium is the primary precipitation hardening element and also conduces to the ferrite formation. Columbium can be successfully substituted for titanium to produce precipitation hardening. Aluminium is added to serve primarily as a deoxidiser, but an excess assists the titanium in making the steel - precipitation hardening.

Carbon does not serve directly in producing the precipitation hardening reaction, as do titanium and aluminium, but it does act as a control on the amount of soluble titanium which is available for the reaction. The behaviour of nitrogen is much the same as carbon since it combines with the titanium and so immobilises it. Nitrogen also stabilises the austenite and therefore must be controlled and held as low as possible (to residual amounts). Nickel, manganese, chromium and silicon serve to control the austenite to ferrite balance.

The temperature range for solution annealing Stainless "W" begins at about 650° C., which is 55°-95° C. above the temperature at which the material begins to transform to austenite and tends to approximately 1,100° C. As the solution annealing temperature rises, hardness and yield strength of the material increase slightly, attaining a maximum between 935° and 1,100° C., while the corresponding tensile strength simultaneously reaches a minimum value at about 870° C. and then increases slightly with increasing temperature.

The minimum holding time is generally short. On thin sections, 5 mins. at temperatures in the higher range (1,010°-1,065° C.) has been found to be satisfactory, and on heavier sections, where it is more difficult to determine when the material has reached a uniform temperature, slightly longer soaking temperatures are recommended. Stainless "W" can be hardened uniformly throughout unusually heavy sections without the difficulties normally attendant upon quenching and surface hardening.

The desired combination of properties determines which of three specific temperatures between 260° and 565° C. shall be used for precipitation hardening (ageing). Lowest ductility with maximum tensile and yield strengths are obtained at 510° C.; improved ductility with slightly lower tensile and yield strengths are obtained at

540° C. If ageing is done at 565° C. ductility is further improved due to the formation of some austenite, but with further sacrifice of tensile and yield strengths.

In the annealed condition, Stainless "W" has a hardness of 22-28 Rockwell C; a tensile strength of 53-67 tons/sq. in. and a yield strength of 33-51 tons/sq. in. By proper heat-treatment hardness can be raised to 39-47 Rockwell C; tensile strength to 87-100 tons/sq. in. and yield strength to 80-94 tons/sq. in. Unlike most other types of 18-8 stainless steel, Stainless "W" is strongly magnetic. Its greatest use is in bar form, but it can be produced in any cast or wrought form including strip, sheet, wire and tubing. Machining is slightly better than that of austenitic 18-8 steel, and fabrication can be achieved easily through spot, metallic arc, atomic hydrogen and helium arc welding, particularly when the material has been solution annealed followed by ageing. Results of 100 hour immersion tests in boiling copper sulphate-sulphuric acid solution, as evaluated by bend tests and microscopic examination, show this steel is not susceptible to intergranular corrosion.

Supersonic Inspection of Metals

By H. R. Clauser

SUPERSONIC inspection methods have been developed within the last few years to the point where they now rank with other non-destructive testing methods, such as radiography, as a means of detecting flaws in materials. To evaluate properly the place of supersonics in the field of flaw detection, two principal supersonic methods must be considered—the reflection method and the through transmission method. In the former supersonic waves are passed through the material and the waves reflected from the opposite side or from flaws are observed, and in the latter the change in energy level of the sound beam when it passes through the material is noted.

The essential parts of the Supersonic Reflectoscope used for the reflection method are: A generator which creates the supersonic waves by applying an oscillatory voltage to a quartz crystal, the quartz crystal which radiates the sound waves into the

material and also receives the back reflections, an electronic amplifier which amplifies the reflected sound waves and a cathode-ray oscilloscope which measures the round-trip time of the waves. In operation the quartz crystal is placed on a flat, relatively smooth surface of the material being tested, after this surface has been covered with a light film of oil or glycerine to improve the sound transmission, and the oscilloscope pattern observed as the crystal is moved over the material. The equipment employs supersonic waves with frequencies in the 500-12,000 kilocycle band. The nature of the material, the kind of flaws being investigated and the size of the test specimen, usually determine the frequency as well as the size of the crystal used (½-2 in. square).

Most metals and plastics can be inspected by the reflection method and the depth of penetration that can be achieved in a given material depends chiefly on the grain structure and the forming method used in its fabrication. Coarse grained materials like copper

From *Materials and Methods*, 1945, Vol. 23, No. 2, pp. 432-433.

From *Materials and Methods*, 1946, Vol. 24, No. 2, pp. 378-384.

and lead are more difficult to penetrate than are aluminium and steel, while forged and wrought products are easier to penetrate than cast parts, Table I. Only defects which offer reflecting surfaces to sound waves can be detected, and the minimum size for detection is a defect having a projected lateral area equal to 0.1% of the distance from the searching crystal to the defect. The reflection method is widely used for the inspection of billets, forged products such as steel axles and stainless steel rotor blanks, tool and die steel stock, and aluminium extrusions.

The essential parts of the Hyper-sonic Analyzer used for the through transmission method are an electronic supersonic generator which creates a signal, a piezoelectric crystal transducer which converts the supersonic signal into mechanical supersonic energy which is transmitted through the material under test, a piezoelectric crystal transducer which services as a receiver of the transmitted sound and converts the mechanical energy into electrical energy, an electronic amplifier which increases the output of the receiver-transducer and an indicating device for signalling the presence of flaws. The frequency of the sound

waves used in this equipment is normally in the region between 50 and 1,000 kilocycles per sec. To give better coupling between the transmitter, the material and the receiver, at supersonic frequencies, the material to be inspected is usually placed in water or oil, although in some applications air or other gases may be used.

Most metallic materials and plastics can be inspected by the supersonic transmission method. Present equipment is capable of examining thickness varying from 0.001-5.0 in. satisfactorily, but the forms or shapes inspected must have a uniform cross-section. Discontinuities with a lateral projected area as small as $\frac{1}{16}$ in. can be accurately located. Typical applications are the inspection of products produced by rolling and extruding such as metal sheets and strip and plastic products, and products from production processes where binding of materials is used.

TABLE I.—MAXIMUM THICKNESS PENETRATED

Material	Approximate Thickness
Aluminium	28 ft.
Steel	25 ft.
Magnesium	30 ft.
Brass	2 ft.
Copper	6 in.
Bakelite	3 in.
Glass	2 ft.

Radiography with Multimillion-Volt X-Rays

By H. R. Clauser

THE most significant accomplishment in the field of radiography during the war years has been the development of X-ray equipment to produce X-rays with energies above one million volts. This development not only makes possible improvements of established applications of radiography for materials inspection, but is also creating entirely new uses and introducing many additional possibilities for radiography. There are, at present, several different methods by which these high energy X-rays are produced. One method uses the electromagnetic generating principle for accelerating electrons and incorporating low frequency resonance transformer apparatus of a design similar to that used for producing one million volt X-rays. This method is limited to the production of X-rays up to two million volts. Another method, employing the elec-

trostatic generator principle, is also capable of producing two million volt X-rays. A third method and the most promising one, is by the acceleration of electrons by means of magnetic induction. This method has made possible the production of X-rays with energies up to 100 million electron volts.

To produce X-rays in the induction electron accelerator, or betatron, electrons are shot into a circular, doughnut-shaped vacuum tube and are caused, by a magnetic field, to describe a circular path. The electrons are continually accelerated around this path in the vacuum tube until they have acquired the desired velocity, when their orbit is expanded by magnetic means and strikes an X-ray producing target. The intensity of the X-ray generated depends upon the characteristics of the equipment and the voltage at which it is operated. With the 100 million volt equipment the intensity at 100 million volts can be as high as

2,600 roentgens per minute at one metre, but when operating at 20 million volts it drops to 180 roentgens. The half value width of the X-ray beam produced in the induction electron accelerator equipment is 5° to 6° at 20 million volts and only 2° at 100 million volts. The 20 million volt equipment has therefore an effective cone of radiation of 10 to 12° which means that, at a working distance of 10 ft. from the focal spot to the film, an area 22 in. square can be X-rayed in one exposure. At the present time electron accelerators are in the engineering development stage and before they receive wide application for metal inspection they will have to be made more mobile and developed to a point where they can easily be maintained and operated by industrial technicians.

In the industrial two million volt X-ray equipment, a 24 section X-ray tube fits inside a low-frequency resonance transformer with both of the elements mounted in a steel tank containing freon gas as an insulating medium. The electrons are emitted by a heated filament at one end of the tube and the high voltage is provided by a resonance transformer which accelerates the electrons in stages of 83,500 volts until they have the desired energy, after which they strike a tungsten target producing X-rays. This unit is capable of X-ray intensities of around 200 roentgens per minute at one metre.

Another tube design capable of producing two-million volt X-rays is operated with an electrostatic generator which produces the required potential. The constant accelerating field over the length of the tube is provided by 180 sections which accelerate the electrons uniformly in stages of 12,000 volts. The tube is used with the electrostatic generator under several hundred pounds air pressure to provide the necessary insulating medium. The X-ray intensities obtained may be as high as 60 roentgens per minute at one metre.

The penetrating power of high energy X-rays increases up to energy levels of around 10 million volts, but above this voltage the rays begin to decrease in their ability to penetrate. Around 25 million volts the penetrating power again begins to increase very slowly until at about 50 million volts and above there seems to be no appreciable change. Higher voltages than 10 million are advantageous, however, in reducing exposure time. With the tremendous increase in penetrating power it is possible to examine

From *Materials and Methods*, 1946, Vol. 23, No. 3, pp. 706-709.

the interior of steel specimens as thick as 18 or 20 inches in the matter of minutes. One million volt equipment is limited to 7 ins. of steel, and using two million volt equipment of the resonance transformer type, it is possible to X-ray 12 in. sections with an exposure of two hours and 8 in. sections in $3\frac{1}{2}$ minutes. With the 20 million volt betatron a 13 in. specimen can be X-rayed in 15 minutes without the use of fluorescent screens.

Absolute sensitivity, although not achieved entirely, is progressively approached with the use of X-rays pro-

duced with energies beginning above one million volts as in multimillion volt radiography the problem of secondary radiation is practically eliminated and sharper definition obtained by the use of an extremely small focal spot. The focal spot in electron accelerator equipment is a minute point generally no larger than 0.01 in. In low-voltage equipments focal spots as large as 0.03 to 0.40 in. are used. The latitude or range of thickness of material over which the radiograph can be taken resulting in film densities which are satisfactory for diagnosis is increased by multimillion volt radiography.

Determination of Nickel and Cobalt in Iron Ores with Preliminary Removal of Iron by Means of Sodium Fluoride

By I. V. Tananaev and V. G. Sil'nichenko

THE basic acetate and other methods of separating iron prior to the determination of nickel and cobalt lead to the formation of voluminous precipitates which tend to retain nickel and cobalt. The determination of nickel by means of dimethylglyoxime may, indeed, be carried out in the presence of iron if the latter element is bound in a complex with tartaric or citric acid, but when the amount of nickel is small and a colorimetric, volumetric, or polarographic method is desirable, the removal of iron may be necessary. Similar considerations apply in the case of small amounts of cobalt.

It is found that a satisfactory separation of iron may be carried out by means of sodium fluoride as a precipitant. A dense, crystalline white precipitate of the composition $5\text{NaF} \cdot 2\text{FeF}_3$ is obtained; it occupies a relatively small volume and shows little tendency to adsorb nickel and cobalt.

Determination of nickel.—In experiments with pure salts, an 8–10% acid solution of ferric chloride, a standard solution of nickel nitrate (0.00063 g. of Ni per 1 ml.), and a 4% aqueous solution of sodium fluoride were used. To a known volume of the iron solution was added a measured volume of the nickel solution and then, after dilution to 60 ml., sufficient caustic soda solution was added to give a cloudiness. The solution was cleared by means of a small excess of hydrochloric acid and treated hot with 100–120 ml. of hot sodium fluoride solution. The pre-

cipitate, which forms at once, was filtered off after 8–10 minutes, the filtrate was neutralized by means of ammonia or sodium acetate, and nickel precipitated as the dimethylglyoxime compound. With 0.5 or

1 g. of Fe and 0.0050 g., 0.0025 g., 0.00126 g., and 0.00063 g. of Ni, the results obtained for Ni were 0.0050 g., 0.0025 g., 0.00126 g., and 0.00067 g. respectively.

Slightly high results were obtained when the amount of sodium fluoride was nearly doubled, but this effect was traced to the presence of SiO_2 in the salt. It is considered that if the sodium fluoride is pure a large excess has no effect on the results.

For the determination in iron ores 1 g. was decomposed by boiling with 15 ml. of hydrochloric acid (sp. gr. 1.19), the solution was diluted to 100 ml., treated with ammonia until only faintly acid and then with sodium fluoride as described above. The results for nickel, 0.28–0.66% for different samples agreed well with those obtained by the classical method.

Determination of cobalt.—After separation of the iron by means of sodium fluoride as in the case of nickel the filtrate was made ammoniacal and electrolysed for cobalt. The results showed that complete separation of iron was attained in one precipitation and that all the cobalt appeared in the filtrate.

Rapid Method of Determining Silica in Blast-Furnace Slag and Silicon in Cast Iron

By N. V. Tananaev

THE method is based upon the use of a solution of joiners' glue as a coagulant of silicic acid.

Silica in cast iron.—0.5 g. of the finely ground slag in a 50–100 ml. beaker is dissolved at a moderate heat in 15–20 ml. of HCl. After complete solution 10 ml. of a 1% solution of joiners' glue are added, and the mixture is stirred for 2–3 minutes. Hot water is then added to make 40–80 ml., the solution is again stirred, and then quickly filtered through a paper in a 5–7 cm. Buchner funnel under slight suction. The precipitate of SiO_2 is transferred to the filter, washed 3–4 times with hot 1% HCl solution, and then 4–5 times with hot water. The filter with precipitate is dried in a porcelain crucible, ignited at 950–1,000°C. and the residue weighed as SiO_2 .

Silicon in cast iron.—1 g. of cast iron in a 100 ml. beaker is dissolved by heating in 20 ml. of a mixture of sulphuric and nitric acids, obtained by mixing 2 l. of H_2SO_4 (sp. gr. 1.84)

with 5.5 l. of distilled water, cooling and adding 1.5 l. of HNO_3 (sp. gr. 1.4). Then 10–15 ml. of hot water and 10 ml. of a 1% solution of joiners' glue are added, the mixture is stirred for 1–2 minutes, diluted to 80 ml. with water, again stirred, and quickly filtered through an 11 cm. paper. The insoluble is transferred to the filter and washed 3–4 times with hot 1% hydrochloric acid and 4–5 times with hot water. The washed precipitate is ignited in a porcelain crucible, ignited at 950–1,000°C. and weighed.

The method has been in use for two years in connection with express determinations in a works laboratory and has given satisfactory results. Analyses may be completed in 30–40 minutes, the precipitate of silicic acid is easily washed, and the ignited silica need not be treated with hydrofluoric acid. The results for cast iron may have to be corrected for the weight of ash contributed by the glue (normally 0.0001–0.0003 g. per 10 ml. of 1% solution). The correction is insignificant in the case of slag.

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